

# The subfamily *Xerocomoideae* (*Boletaceae*, *Boletales*) in China

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**Abstract:** *Xerocomoideae* is an ecologically and economically important *Boletaceae* subfamily (*Boletales*) comprising 10 genera. Although many studies have focused on *Xerocomoideae* in China, the diversity, taxonomy and molecular phylogeny still remained incompletely understood. In the present study, taxonomic and phylogenetic studies on Chinese species of *Xerocomoideae* were carried out by morphological examinations and molecular phylogenetic analyses. Eight genera in *Xerocomoideae*, viz. *Aureoboletus*, *Boletellus*, *Heimioporus*, *Hemileccinum*, *Hourangia*, *Phylloporus*, *Pulchroboletus*, and *Xerocomus* were confirmed to be distributed in China; 97 species of the subfamily were accepted as being distributed in China; one ambiguous taxon was tentatively named *Bol. aff. putuoensis*; two synonyms, viz. *A. marroninus* and *P. dimorphus* were defined. Among the Chinese accepted species, 13 were newly described, viz. *A. albipes*, *A. conicus*, *A. ornatipes*, *Bol. erythrolepis*, *Bol. rubidus*, *Bol. sinochrysenderoides*, *Bol. subglobosus*, *Bol. zenghuoxingii*, *H. squamipes*, *P. hainanensis*, *Pul. erubescens*, *X. albotomentosus*, and *X. fuscatus*, 36 known species were redescribed, and the other 48 species were reviewed. Keys to accepted species of *Aureoboletus*, *Boletellus*, *Heimioporus*, *Hemileccinum*, *Hourangia*, *Phylloporus*, and *Xerocomus* in China were also provided.

**Key words:** Bolete, molecular phylogeny, morphology, new taxa, taxonomy.

**Taxonomic novelties: New species:** *Aureoboletus albipes* N.K. Zeng, Xu Zhang & Zhi Q. Liang, *A. conicus* N.K. Zeng, Xu Zhang & Zhi Q. Liang, *A. ornatipes* N.K. Zeng, Xu Zhang & Zhi Q. Liang, *Boletellus erythrolepis* N.K. Zeng, R. Xue, S. Jiang & Zhi Q. Liang, *Bol. rubidus* N.K. Zeng, R. Xue, Y.J. Hao & Zhi Q. Liang, *Bol. sinochrysenderoides* N.K. Zeng, R. Xue & Kuan Zhao, *Bol. subglobosus* N.K. Zeng, R. Xue, S. Jiang & Zhi Q. Liang, *Bol. zenghuoxingii* N.K. Zeng, R. Xue, S. Jiang & Zhi Q. Liang, *Hemileccinum squamipes* N.K. Zeng, Chang Xu & Zhi Q. Liang, *Phylloporus hainanensis* N.K. Zeng, L.L. Wu, & Zhi Q. Liang, *Pulchroboletus erubescens* N.K. Zeng, Chang Xu & Zhi Q. Liang, *Xerocomus albotomentosus* N.K. Zeng, H.J. Xie, Chang Xu & Zhi Q. Liang, and *X. fuscatus* N.K. Zeng, H.J. Xie, Chang Xu & Zhi Q. Liang.

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## INTRODUCTION

Ongoing phylogenetic studies have confirmed that the subfamily *Xerocomoideae* (*Boletaceae*, *Boletales*) includes 10 genera, viz. *Alessioporus*, *Aureoboletus*, *Boletellus*, *Heimioporus*, *Hemileccinum*, *Hourangia*, *Phylloporus*, *Pulchroboletus*, *Rubinosporus*, and *Xerocomus* (Nuhn *et al.* 2013, Gelardi *et al.* 2014, Halling *et al.* 2015, Zhu *et al.* 2015, Wu *et al.* 2016, Loizides *et al.* 2019, Wagensommer *et al.* 2021, Vadthananarat *et al.* 2022). Two additional genera, *Comeroboletus* and *Sinoboletus*, were initially described in the subfamily but were later synonymised with *Hemileccinum* and *Aureoboletus*, respectively (Wu *et al.* 2016, Vadthananarat *et al.* 2022). *Xerocomoideae* has received much attention, and abundant species within the subfamily have been elucidated (Pouzar 1957, Horak 1977, Pegler & Young 1981, Luis & Gómez 1996, Fulgenzi *et al.* 2008, Šutara 2008, Kasom & Karadelev 2012, Husbands *et al.* 2013, Gelardi *et al.* 2014, Ayala-Vásquez *et al.* 2018, Loizides *et al.* 2019, Wagensommer *et al.* 2021, Vadthananarat *et al.* 2022). Besides species

richness, the medicinal values, edibility, and poisonousness of *Xerocomoideae* have also been noted by mycologists. For example, *H. depilatum* was shown to have antioxidant activity (Alkan *et al.* 2020); one lectin from *X. chrysenteron* showed potent insecticidal activity (Birck *et al.* 2004, Karimi *et al.* 2008); wild basidiocarps of *P. luxiensis* were sold as edibles in the markets (Wu *et al.* 2021), and *Hei. japonicus* was believed to be poisonous, causing gastroenteritis (Wang *et al.* 2022).

In China, mycologists have also carried out a series of in-depth studies on the species of *Xerocomoideae*, resulting in the discovery of numerous new taxa that have significantly enriched the species diversity of this subfamily (Chiu 1948, 1957, Teng 1963, Bi *et al.* 1982, Zang 1985, Li *et al.* 1992, Chen *et al.* 2002, Wang & Liu 2002, Zeng & Yang 2011, Zeng *et al.* 2013, 2015, Zhu *et al.* 2015, Wu *et al.* 2016, Zhang *et al.* 2019a, Li *et al.* 2021, Wu *et al.* 2021, Lin *et al.* 2022). Despite these findings, the diversity, taxonomy, and molecular phylogeny remain incompletely understood. This study aimed to improve our understanding of *Xerocomoideae* by examining collections from various regions of China, re-examining

holotypes of previously described species, and conducting phylogenetic analyses using multilocus DNA sequence data. The study described new taxa of *Xerocomoideae* in China and re-evaluated previously described/reported species, with the goal of contributing to our knowledge of this subfamily.

## MATERIALS AND METHODS

### Abbreviations of generic names used in the study

The abbreviations of *Alessiaporus*, *Aureoboletus*, *Boletus*, *Boletellus*, *Heimioporus*, *Hemileccinum*, *Hourangia*, *Phylloporus*, *Pulchroboletus*, *Xerocomus*, mentioned in this work are *Ale.*, *A.*, *B.*, *Bol.*, *Hei.*, *H.*, *Hou.*, *P.*, *Pul.* and *X.*, respectively.

### Morphological studies

The fresh basidiomata were described and photographed in the field, then dried at about 60 °C for 12 h. The dried specimens were deposited at the Fungarium of Hainan Medical University, Haikou City, Hainan Province, China (FHMU), the Herbarium of Cryptogams, Kunming Institute of Botany, Chinese Academy of Sciences (HKAS), the Fungarium of Mycology, Chinese Academy of Sciences (HMAS), or the Fungarium of the Guangdong Institute of Microbiology (GMGD).

Colour codes are from Kornerup & Wanscher (1981). Sections of the pileipellis were cut tangentially and halfway between the centre and margin of the pileus. Sections of the stipeipellis were taken from the middle part along the longitudinal axis of the stipe. Five percent KOH was used as the mounting medium for the microscopic studies. All microscopic structures were drawn freehand from materials rehydrated in 5 % KOH. Microscopic structures were examined under a compound light microscope (CX23, Olympus, Tokyo, Japan), and the light micrographs of basidiospores were taken under a compound light microscope (DM2500, Leica, Germany). Basidiospores of dried specimens were examined with a Hitachi S-4800 (Tokyo, Japan) or a Zeiss Sigma 300 (Germany) scanning electron microscope (SEM) (Zeng *et al.* 2013). The number of measured basidiospores is given as 'n/m/p', indicating that the measurements were taken on 'n' basidiospores from 'm' basidiomata of 'p' collections. The basidiospore dimensions are given as '(a–)b–c(–d)', where the range 'b–c' represents a minimum of 90 % of the measured value (5th to 95th percentile), and extreme values ('a' and 'd') (a < 5th percentile, d > 95th percentile) are in parentheses. 'Q' refers to the length/width ratio of the basidiospores; 'Qm' refers to the average Q of the basidiospores and is given with a sample standard deviation.

### DNA extraction, primers, PCR and sequencing

Total genomic DNA was obtained with Plant Genomic DNA Kit (TIANGEN Company, China) from materials dried with silica gel according to the manufacturer's instructions. The primers used were LR0R/LR5 (Vilgalys & Hester 1990, James *et al.* 2006) for amplifying the nuclear ribosomal large subunit RNA (28S), ITS5/ITS4 (White *et al.* 1990) for the nuclear rDNA region encompassing the internal transcribed spacers 1 and 2, along with the 5.8S rDNA (ITS), EF1-2F/EF1-2R (Zeng *et al.* 2013) for the translation elongation factor 1- $\alpha$  gene (*tef1*), and bRPB2-6F/bRPB2-7.1R (Matheny 2013) for the RNA polymerase II second largest subunit gene (*rpb2*). PCR products

were checked in 1 % (w/v) agarose gels, and positive reactions with a bright single band were purified and directly sequenced using an ABI 3730xl DNA Analyzer (Guangzhou Branch of BGI, China) with the same primers used for PCR amplifications. Assembled sequences were deposited in GenBank (Table 1).

### Dataset assembly

For the concatenated multilocus dataset of *Aureoboletus*, 68 sequences (43 of 28S, 22 of *tef1*, and three of *rpb2*) from 47 specimens were newly generated (Table 1), and then combined with sequences of described/undescribed *Aureoboletus* species (Supplementary Table S1). *Phylloporus imbricatus*, X. aff. *subtomentosus* and *Xerocomus* sp. were used as outgroups following Zhang *et al.* (2019a). For the concatenated multilocus dataset of *Boletellus*, 139 sequences (67 of 28S, 57 of *tef1*, and 15 of *rpb2*) from 74 collections were newly generated (Table 1), and then combined with sequences of described/undescribed *Boletellus* species (Supplementary Table S1). *Heimioporus subretisporus* was chosen as the outgroup from Xu *et al.* (2022). For the concatenated multilocus dataset of *Hemileccinum*, 22 sequences (eight of 28S, eight of ITS, and six of *tef1*) from eight collections were newly generated (Table 1), and then combined with sequences of described/undescribed *Hemileccinum* species (Supplementary Table S1). *Aureoboletus erythraeus* was chosen as the outgroup based on Wang *et al.* (2020). For the concatenated dataset of *Phylloporus*, 67 sequences (33 of 28S, 18 of ITS, and 16 of *tef1*) from 35 collections were newly generated (Table 1), and then combined with sequences of described/undescribed *Phylloporus* species (Supplementary Table S1). *Hourangia cheoi* was chosen as the outgroup from Wu *et al.* (2021). For the concatenated multilocus dataset of *Pulchroboletus*, five sequences (three of 28S, and two of ITS) from three collections were newly generated (Table 1), and then combined with sequences of described species of *Alessiaporus* and *Pulchroboletus* (Supplementary Table S1). *Hemileccinum impolitum* was chosen as the outgroup on the basis of Gelardi *et al.* (2014). For the concatenated multilocus dataset of *Xerocomus*, 44 sequences (18 of 28S, 18 of ITS, and eight of *tef1*) from 21 collections were newly generated (Table 1), and then combined with sequences of described/undescribed *Xerocomus* species (Supplementary Table S1). *Phylloporus brunneiceps* was chosen as the outgroup according to Wu *et al.* (2016).

To test for phylogenetic conflict among the different genes in the six combined dataset, the single-gene phylogenetic trees based on 28S, ITS, *tef1*, and *rpb2*, respectively, were analysed and found to not be in conflict. Then the sequences of different genes in the six combined dataset were aligned using MUSCLE v. 3.6 (Edgar 2004), and manually adjusted where necessary in BioEdit v. 7.0.9 (Hall 1999). The sequences of the different genes were concatenated using Phyutility v. 2.2 for further analyses (Smith & Dunn 2008).

### Phylogenetic analyses

The six combined datasets (*Aureoboletus*, *Boletellus*, *Hemileccinum*, *Phylloporus*, *Pulchroboletus*, *Xerocomus*) were all analysed by using maximum likelihood (ML) and Bayesian inference (BI). Maximum likelihood tree generation and bootstrap analyses were performed with the program RAxML v. 7.2.6 (Stamatakis 2006) running 1 000 replicates combined with an ML search. Bayesian analyses with MrBayes v. 3.1 (Huelsenbeck & Ronquist 2005) implementing the Markov Chain Monte Carlo (MCMC) technique and parameters predetermined with MrModeltest v. 2.3 (Nylander 2004) were performed.



**Table 1.** Taxa, vouchers, locations, and GenBank accession numbers of newly generated sequences used in this study.

Species	Voucher	Locality	GenBank accession No.			
			28S	ITS	<i>tef1</i>	<i>rpb2</i>
<i>Aureoboletus albipes</i>	N.K. Zeng3267 (FHMU2228)	Fujian, SE China	OP630876	OP696773	OP676221	—
	N.K. Zeng3276 (FHMU2237)	Fujian, SE China	OP630877	OP696774	OP676222	—
<i>A. clavatus</i>	N.K. Zeng3518 (FHMU2978)	Hainan, southern China	—	OP696775	—	—
	N.K. Zeng3446 (FHMU2885)	Hainan, southern China	OP604278	—	OP676225	—
<i>A. conicus</i>	N.K. Zeng4276 (FHMU4730)	Hainan, southern China	OP630878	—	—	—
<i>A. duplicatoporus</i>	Y.Q. Fu104 (FHMU5068)	Hainan, southern China	OP605388	—	OP680532	—
	H.Y. Huang780 (FHMU5907)	Hainan, southern China	OP605389	—	—	—
	N.K. Zeng2417 (FHMU3335)	Hainan, southern China	OP605390	—	—	OP680536
	N.K. Zeng2979 (FHMU1940)	Hainan, southern China	OP605391	—	—	—
	N.K. Zeng3007 (FHMU1968)	Hainan, southern China	OP605392	—	—	—
	N.K. Zeng4428 (FHMU4731)	Hainan, southern China	—	—	OP680533	—
	N.K. Zeng4429 (FHMU4736)	Hainan, southern China	—	—	OP680534	—
	N.K. Zeng4712 (FHMU4912)	Hainan, southern China	OP605393	—	—	—
	N.K. Zeng4729-1 (FHMU5398)	Hainan, southern China	OP605394	—	OP680535	—
	N.K. Zeng4684 (FHMU4911)	Hainan, southern China	OP605395	—	—	—
	N.K. Zeng3288 (FHMU2249)	Fujian, SE China	OP615077	OP615084	OP680537	—
	LWF8 (FHMU5851)	Zhejiang, eastern China	OP615078	—	OP680538	—
	N.K. Zeng3134 (FHMU2095)	Hainan, southern China	OP615079	—	—	—
	N.K. Zeng3136 (FHMU2097)	Hainan, southern China	OP615080	—	—	—
<i>A. longicollis</i>	N.K. Zeng3129 (FHMU2090)	Hainan, southern China	OP615081	OP615085	—	—
	S. Jiang120 (FHMU4577)	Hainan, southern China	OP615082	—	—	—
	N.K. Zeng4464 (FHMU4716)	Hainan, southern China	OP604279	—	—	—
	N.K. Zeng4709 (FHMU4964)	Hainan, southern China	OP615086	OP629170	OP680539	—
	N.K. Zeng3077 (FHMU2038)	Hainan, southern China	OP615087	OP629171	OP680540	—
<i>A. miniatoaurantiacus</i>	FHMU6977	Yunnan, SW China	OP615088	OP629172	OP680541	—
	N.K. Zeng3020 (FHMU1981)	Hainan, southern China	OP630879	—	OP676223	OP676224
<i>A. raphanaceus</i>	N.K. Zeng3205 (FHMU2166)	Hainan, southern China	OP615089	OP629173	—	—
	N.K. Zeng2007 (FHMU3597)	Hainan, southern China	OP615090	OP629174	OP680542	OP680545
<i>A. rubellus</i>	N.K. Zeng2007-1 (FHMU7598)	Hainan, southern China	OP615091	OP629175	OP680543	—
	S.D. Yang211 (FHMU5516)	Yunnan, SW China	OP615092	—	OP680544	—
	N.K. Zeng4592 (FHMU4877)	Hainan, southern China	OP604280	OP696776	OP676226	—
	Y.Q. Fu002 (FHMU4453)	Hainan, southern China	OP604281	—	OP676227	—
	N.K. Zeng3494 (FHMU3117)	Hainan, southern China	OP615107	—	OP680546	—
<i>A. solus</i>	N.K. Zeng1064 (FHMU715)	Hainan, southern China	OP615108	—	—	—
	N.K. Zeng812 (FHMU489)	Hainan, southern China	OP615109	—	—	—
	N.K. Zeng4146-1 (FHMU4377)	Hainan, southern China	OP615110	OP629165	OP680547	—
<i>Aureoboletus</i> sp.	N.K. Zeng4203 (FHMU6976)	Hainan, southern China	OP615111	OP629166	—	—
	L.P. Tang2077 (FHMU5505)	Yunnan, SW China	OP615112	OP629167	—	—
	N.K. Zeng4666 (FHMU4919)	Hainan, southern China	OP615113	OP629168	—	—
<i>A. tenuis</i>	N.K. Zeng3264 (FHMU2225)	Fujian, SE China	OP615201	OP629160	—	—
	N.K. Zeng1296-1 (FHMU7496)	Fujian, SE China	OP615202	—	—	—
<i>A. venustus</i>	S. Jiang259 (FHMU4784)	Hainan, southern China	OP615203	OP629161	—	—
	S. Jiang256 (FHMU4776)	Hainan, southern China	OP615204	OP629162	OP680548	—
	N.K. Zeng3180-1 (FHMU7494)	Hainan, southern China	OP625205	OP629163	—	—
	N.K. Zeng3345 (FHMU3146)	Hainan, southern China	—	OP629164	—	—
<i>A. viscidipes</i>	S.D. Yang176 (FHMU5526)	Yunnan, SW China	OP615206	—	—	—
<i>A. yunnanensis</i>	N.K. Zeng623 (FHMU392)	Fujian, SE China	OP615207	—	—	—
<i>Boletellus</i> aff. <i>putuoensis</i>	N.K. Zeng3207 (FHMU2168)	Hainan, southern China	—	—	MW925902	—

Table 1. (Continued).

Species	Voucher	Locality	GenBank accession No.			
			28S	ITS	tef1	rpb2
<i>Bol. areolatus</i>	N.K. Zeng3085 (FHMU2046)	Hainan, southern China	MT829118	—	MW925881	MW925938
	N.K. Zeng3112 (FHMU2073)	Hainan, southern China	MW826852	OP681711	MW925880	—
	KUN-HKAS99767	Yunnan, SW China	MW826851	—	MW925879	—
<i>Bol. brunoflavus</i>	N.K. Zeng1271 (FHMU3249)	Fujian, SE China	MW826894	OP681695	—	—
	N.K. Zeng1271-1 (FHMU3250)	Fujian, SE China	MW826895	OP681701	—	—
	N.K. Zeng2913 (FHMU1885)	Hainan, southern China	MW826896	—	MW925920	MW925949
	KUN-HKAS53375	Fujian, SE China	KF112364	—	KF112240	KF112748
<i>Bol. emodensis</i>	N.K. Zeng1340 (FHMU892)	Fujian, SE China	MW826871	—	—	—
	N.K. Zeng2488 (FHMU1611)	Hainan, southern China	MW826862	OP681697	—	MW925942
	N.K. Zeng2536 (FHMU1649)	Hainan, southern China	MT829120	—	MW925889	—
	N.K. Zeng2934 (FHMU1904)	Hainan, southern China	MW826860	—	—	—
	N.K. Zeng3037 (FHMU1998)	Hainan, southern China	MT829119	—	MW925887	MW925944
	N.K. Zeng3070 (FHMU2031)	Hainan, southern China	MW826857	OP681702	MW925890	—
	N.K. Zeng3073 (FHMU2034)	Hainan, southern China	MT829121	—	MW925888	MW925945
	N.K. Zeng3103 (FHMU2064)	Hainan, southern China	MW826858	OP681703	MW925886	—
	N.K. Zeng3184 (FHMU2145)	Hainan, southern China	MW826859	—	MW925884	—
	N.K. Zeng3191 (FHMU2152)	Hainan, southern China	MW826867	OP681707	—	—
	N.K. Zeng3193 (FHMU2154)	Hainan, southern China	MW826866	OP681708	—	—
	N.K. Zeng3243 (FHMU2204)	Fujian, SE China	MW826861	—	MW925883	—
	N.K. Zeng3260 (FHMU2221)	Fujian, SE China	MW826872	OP681705	MW925895	MW925943
	N.K. Zeng3284 (FHMU2245)	Fujian, SE China	MW826863	OP681704	MW925894	MW925940
	N.K. Zeng3490 (FHMU3252)	Hainan, southern China	MW826870	—	MW925896	—
	S. Jiang54 (FHMU3253)	Hainan, southern China	MW826869	OP681698	—	—
	S. Jiang63 (FHMU3254)	Hainan, southern China	MW826864	OP681699	—	—
	R. Xue10 (FHMU3306)	Hainan, southern China	—	—	MW925891	—
	R. Xue13 (FHMU3307)	Hainan, southern China	—	—	MW925885	—
	R. Xue14 (FHMU3308)	Hainan, southern China	—	—	MW925893	—
	R. Xue17 (FHMU3309)	Hainan, southern China	—	—	MW925892	—
	N.K. Zeng4242 (FHMU3310)	Hainan, southern China	MW826899	—	MW925926	—
	S. Jiang83 (FHMU3311)	Hainan, southern China	MW826868	—	MW925897	MW925941
	KUN-HKAS80481	Guangdong, southern China	MW826903	—	—	—
	KUN-HKAS99918	Hunan, central China	MW826865	—	—	—
<i>Bol. erythrolepis</i>	N.K. Zeng1362 (FHMU913)	Fujian, SE China	MW826846	—	MW925875	—
	S. Jiang78 (FHMU3255)	Hainan, southern China	MW826909	—	MW925927	—
	S. Jiang78-1 (FHMU3312)	Hainan, southern China	MW826847	—	—	—
	S. Jiang78-2 (FHMU3313)	Hainan, southern China	MW826848	—	—	—
	S. Jiang78-3 (FHMU3314)	Hainan, southern China	MW826845	—	MW925876	—
<i>Bol. indistinctus</i>	N.K. Zeng649 (FHMU412)	Fujian, SE China	MW826881	—	—	—
	N.K. Zeng1333 (FHMU886)	Fujian, SE China	MW826880	—	MW925916	—
	N.K. Zeng1388 (FHMU936)	Fujian, SE China	MW826879	—	MW925911	—
	N.K. Zeng1393 (FHMU940)	Fujian, SE China	MW826878	OP681696	MW925907	—
	N.K. Zeng1624 (FHMU1088)	Fujian, SE China	MW826873	OP681700	MW925912	MW925948
	N.K. Zeng2470 (FHMU1596)	Hainan, southern China	MT829116	—	MW925910	—
	N.K. Zeng3067 (FHMU2028)	Hainan, southern China	MT829117	—	MW925905	—
	N.K. Zeng3188 (FHMU2149)	Hainan, southern China	MW826875	OP681706	MW925909	—
	N.K. Zeng3298 (FHMU2259)	Fujian, SE China	MW826874	OP681709	MW925915	—
	N.K. Zeng3308 (FHMU2269)	Fujian, SE China	MW826876	OP681710	MW925906	—

Table 1. (Continued).

Species	Voucher	Locality	GenBank accession No.			
			28S	ITS	tef1	rpb2
<i>Bol. putuoensis</i>	N.K. Zeng3652 (FHMU2852)	Hainan, southern China	MW826887	—	MW925917	—
	R. Xue3 (FHMU3315)	Hainan, southern China	MW826886	—	MW925919	—
	Y.Q. Fu91 (FHMU3316)	Hainan, southern China	MW826882	—	MW925908	—
	Y.Q. Fu99 (FHMU3317)	Hainan, southern China	MW826883	—	MW925914	—
	N.K. Zeng4000 (FHMU3318)	Hainan, southern China	MW826885	—	MW925918	—
	N.K. Zeng4002 (FHMU3319)	Hainan, southern China	MW826884	—	MW925913	—
	N.K. Zeng4134 (FHMU3320)	Guangdong, southern China	MW826900	—	MW925923	—
	N.K. Zeng4135 (FHMU3321)	Guangdong, southern China	MW826898	—	MW925922	—
	N.K. Zeng4137 (FHMU3322)	Guangdong, southern China	—	—	MW925924	—
	KUN-HKAS84677	Yunnan, SW China	MW826877	—	—	—
<i>Bol. rubidus</i>	N.K. Zeng3186 (FHMU2147)	Hainan, southern China	MW826892	—	MW925900	—
	N.K. Zeng4070 (FHMU3260)	Guangdong, southern China	MW826890	—	MW925899	—
	N.K. Zeng4075 (FHMU3261)	Guangdong, southern China	MW826891	—	MW925901	—
<i>Bol. sinochrysenteroides</i>	FHMU3267	Yunnan, SW China	MW826849	—	MW925877	—
	KUN-HKAS58713	Yunnan, SW China	KF112428	—	KF112307	KF112759
	KUN-HKAS83069	Yunnan, SW China	MW826904	—	—	—
<i>Bol. squamosus</i>	K. Zhao998 (FHMU3264)	Jiangxi, eastern China	MW826902	—	MW925904	MW925947
	K. Zhao925 (FHMU3265)	Zhejiang, eastern China	MW826901	—	MW925903	MW925946
<i>Bol. subglobosus</i>	N.K. Zeng4051 (FHMU3266)	Hainan, southern China	MW826856	—	MW925898	—
	KUN-HKAS59536	Yunnan, SW China	KF112427	—	KF112306	KF112758
	S. Jiang100 (FHMU3256)	Hainan, southern China	MW826844	—	MW925872	—
<i>Bol. zenghuoxingii</i>	S. Jiang99 (FHMU3257)	Hainan, southern China	MW826843	—	MW925874	—
	S. Jiang98 (FHMU3258)	Hainan, southern China	MW826842	—	MW925873	—
	N.K. Zeng2506 (FHMU3259)	Hainan, southern China	—	—	MW925871	—
	N.K. Zeng3018 (FHMU1979)	Hainan, southern China	MW826855	—	MW925878	MW925939
<i>Hemileccinum ferrugineipes</i>	N.K. Zeng2553 (FHMU3251)	Hainan, southern China	MW826854	—	—	—
	N.K. Zeng3309-1 (FHMU7597)	Fujian, SE China	OP630823	OP630842	OP676216	—
	Y.J. Pu 286 (FHMU7591)	Yunnan, SW China	OP630822	OP630841	OP676215	—
	N.K. Zeng1342 (FHMU894)	Fujian, SE China	OP630824	OP630843	—	—
<i>H. rugosum</i>	N.K. Zeng2978 (FHMU1939)	Hainan, southern China	OP630825	OP630844	OP676217	—
	N.K. Zeng3388 (FHMU2966)	Hainan, southern China	OP630826	OP630845	OP676218	—
	N.K. Zeng3555 (FHMU3069)	Yunnan, SW China	OP630819	OP630838	—	—
<i>H. squamipes</i>	N.K. Zeng4586 (FHMU4902)	Hainan, southern China	OP630820	OP630839	OP676213	—
	N.K. Zeng2572 (FHMU1679)	Hainan, southern China	OP630821	OP630840	OP676214	—
	N.K. Zeng4783 (FHMU5428)	Hainan, southern China	ON527844	—	ON868512	—
	N.K. Zeng4784 (FHMU5408)	Hainan, southern China	ON527845	—	ON868513	—
<i>Phylloporus alboinfuscatus</i>	N.K. Zeng4787 (FHMU5450)	Hainan, southern China	ON527846	—	ON868514	—
	W.H. Zhang390 (FHMU4990)	Yunnan, SW China	ON527824	—	—	—
	H.Y. Huang745 (FHMU4986)	Yunnan, SW China	ON527823	—	—	—
<i>P. bellus</i>	H.Y. Huang747 (FHMU4983)	Yunnan, SW China	ON527821	ON527854	—	—
	FHMU6489	Yunnan, SW China	ON527822	—	—	—
	N.K. Zeng4625 (FHMU4994)	Hainan, southern China	ON527820	ON527853	—	—
	N.K. Zeng4629 (FHMU4978)	Hainan, southern China	ON527819	ON527852	—	—
	N.K. Zeng4655 (FHMU4995)	Hainan, southern China	ON527818	ON527851	—	—



Table 1. (Continued).

Species	Voucher	Locality	GenBank accession No.			
			28S	ITS	tef1	rpb2
<i>P. castanopsidis</i>	N.K. Zeng4788 (FHMU5400)	Hainan, southern China	ON527843	—	—	—
	N.K. Zeng4789 (FHMU5413)	Hainan, southern China	ON527842	—	ON868511	—
<i>P. grossus</i>	KUN-HKAS82703	China	ON527840	—	—	—
	N.K. Zeng4263 (FHMU4746)	Hainan, southern China	ON527841	—	—	—
	N.K. Zeng4304 (FHMU4556)	Hainan, southern China	ON527839	—	—	—
	N.K. Zeng4810 (FHMU5035)	Hainan, southern China	ON527835	—	ON868507	—
	N.K. Zeng4815 (FHMU5025)	Hainan, southern China	ON527838	—	ON868510	—
	N.K. Zeng4817 (FHMU4988)	Hainan, southern China	ON527836	—	ON868508	—
	L.Y. Liu 3 (FHMU6944)	Hainan, southern China	ON527837	—	ON868509	—
	N.K. Zeng4272 (FHMU4723)	Hainan, southern China	ON527827	ON527857	—	—
<i>P. hainanensis</i>	N.K. Zeng4984 (FHMU5550)	Hainan, southern China	ON527828	ON527858	ON868501	—
	W.H. Zhang367 (FHMU6088)	Yunnan, SW China	ON527847	—	ON868515	—
<i>P. luxiensis</i>	FHMU6487	Yunnan, SW China	ON527850	ON527867	—	—
<i>P. nigrisquamus</i>	N.K. Zeng4477 (FHMU3340)	Hainan, southern China	ON527826	ON527856	—	—
<i>P. parvisporus</i>	N.K. Zeng4466 (FHMU3361)	Hainan, southern China	ON527849	ON527866	—	—
	N.K. Zeng4610 (FHMU5010)	Hainan, southern China	—	ON527868	—	—
	N.K. Zeng4287 (FHMU4719)	Hainan, southern China	ON527830	ON527860	—	—
<i>P. rubiginosus</i>	N.K. Zeng4828 (FHMU5377)	Hainan, southern China	ON527834	ON527864	ON868506	—
	N.K. Zeng4833 (FHMU5378)	Hainan, southern China	—	ON527861	ON868504	—
	N.K. Zeng4834 (FHMU5365)	Hainan, southern China	ON527832	ON527862	—	—
	N.K. Zeng4836 (FHMU5382)	Hainan, southern China	ON527833	ON527863	ON868505	—
	N.K. Zeng4993 (FHMU4800)	Hainan, southern China	ON527831	—	ON868503	—
	N.K. Zeng5009 (FHMU4791)	Hainan, southern China	ON527829	ON527859	ON868502	—
	N.K. Zeng4293 (FHMU4741)	Hainan, southern China	ON527825	ON527855	—	—
	N.K. Zeng4588 (FHMU4891)	Hainan, southern China	ON527848	ON527865	ON868516	—
<i>Phylloporus</i> sp.	S. Jiang 52 (FHMU7592)	Hainan, southern China	OP630827	OP630846	OP676219	—
<i>P. subrupeolus</i>	N.K. Zeng4302 (FHMU4710)	Hainan, southern China	OP630828	OP630847	—	—
	N.K. Zeng4274 (FHMU4543)	Hainan, southern China	OP630829	—	OP676220	—
	N.K. Zeng4104 (FHMU3794)	Guangdong, southern China	ON652304	ON652308	—	—
<i>Xerocomus albotomentosus</i>	N.K. Zeng3395 (FHMU2974)	Hainan, southern China	—	ON641116	ON660580	—
	N.K. Zeng3611 (FHMU2825)	Yunnan, SW China	ON641093	ON641109	ON660581	—
	N.K. Zeng3190 (FHMU2151)	Hainan, southern China	—	ON641115	—	—
	N.K. Zeng4678 (FHMU4922)	Hainan, southern China	ON641097	ON641111	ON660585	—
	N.K. Zeng4677 (FHMU4925)	Hainan, southern China	ON641098	ON641112	ON660586	—
	N.K. Zeng4672 (FHMU4967)	Hainan, southern China	ON641099	ON641113	ON660587	—
	N.K. Zeng4664 (FHMU4940)	Hainan, southern China	ON641100	ON641114	—	—
	H.Y. Huang490 (FHMU6029)	Yunnan, SW China	ON641095	—	ON660582	—
<i>X. rugosellus</i>	H.Y. Huang529 (FHMU6011)	Yunnan, SW China	ON641096	—	ON660583	—
	N.K. Zeng3794 (FHMU4718)	China	ON641094	ON641110	—	—
<i>Xerocomus</i> sp.	Y. Li3166 (FHMU6904)	Zhejiang, eastern China	ON652305	ON652310	—	—
<i>X. subparvus</i>	Y. Li3109 (FHMU6901)	Zhejiang, eastern China	—	ON652309	—	—
	N.K. Zeng2510 (FHMU1630)	Hainan, southern China	ON641086	ON641102	—	—
	N.K. Zeng3280 (FHMU2241)	Fujian, SE China	ON641087	ON641103	—	—
	N.K. Zeng4049 (FHMU3344)	Hainan, southern China	ON641088	ON641104	—	—
	FHMU6121	Hunan, central China	ON641101	—	ON660584	—
	FHMU7595	Yunnan, SW China	ON641089	ON641105	—	—
	FHMU7596	Yunnan, SW China	ON641090	ON641106	—	—

Table 1. (Continued).

Species	Voucher	Locality	GenBank accession No.			
			28S	ITS	<i>tef1</i>	<i>rpb2</i>
	N.K. Zeng3559 (FHMU3071)	Yunnan, SW China	ON641091	ON641107	—	—
	N.K. Zeng3561 (FHMU3059)	Yunnan, SW China	ON641092	ON641108	—	—

Note: SE = southeastern, SW = southwestern.

For the combined dataset of *Aureoboletus*, the best-fit likelihood models of 28S, *tef1*, and *rpb2* were GTR + I + G, GTR + G, and SYM + I + G, respectively; for the combined dataset of *Boletellus*, the best-fit likelihood models of 28S, *tef1*, and *rpb2* were GTR+I+G, K80+I+G, and SYM+I, respectively; for the combined dataset of *Hemileccinum*, the best-fit likelihood models of 28S, ITS, and *tef1* were GTR+I+G, GTR+G, and SYM+G, respectively; for the combined dataset of *Phylloporus*, the best-fit likelihood models of 28S, ITS, and *tef1* were GTR + I + G, GTR + I + G, and K80 + I + G, respectively; for the combined dataset of *Pulchroboletus*, the best-fit likelihood models of 28S and ITS were GTR + I + G and HKY + G, respectively; for the combined dataset of *Xerocomus*, the best-fit likelihood models of 28S, ITS, and *tef1* were GTR + I + G, GTR + I + G, and SYM + I + G, respectively. Bayesian analysis of the six datasets were run for 30, 40, 0.2, 30, 0.8, and 8 million generations, respectively, and sampled every 100. Trees sampled from the first 25 % of the generations were discarded as burn-in, and Bayesian posterior probabilities (PP) were then calculated for a majority consensus tree of the retained Bayesian trees. Runs were terminated once the average standard deviation of split frequencies dropped below 0.01.

## RESULTS

### Molecular data

The combined dataset (28S + *tef1* + *rpb2*) of *Aureoboletus* included 250 taxa with 2 262 nucleotide sites. Tree topologies generated by BI and ML analyses were identical, albeit there were slight differences in statistical support for some relationships. Figure 1 shows a branch-length phylogram inferred with RAxML with support values. The collections of *Aureoboletus* in China were grouped into 37 independent species-level lineages (Fig. 1).

The combined dataset (28S + *tef1* + *rpb2*) of *Boletellus* included 168 taxa with 2 165 nucleotide sites (Fig. 2). Tree topologies generated by BI and ML analyses were identical, albeit there were slight differences in statistical support for some relationships. Figure 2 shows a branch-length phylogram inferred with RAxML with support values. The collections of *Boletellus* in China were grouped into 15 independent species-level lineages (Fig. 2).

The combined dataset (28S + ITS + *tef1*) of *Hemileccinum* included 43 taxa with 2 457 nucleotide sites. Tree topologies generated by BI and ML analyses were identical, albeit there were slight differences in statistical support for some relationships. Figure 3 shows a branch-length phylogram inferred with RAxML with support values. The collections of *Hemileccinum* in China were grouped into seven independent species-level lineages (Fig. 3).

The combined dataset (28S + ITS + *tef1*) of *Phylloporus* included 209 taxa with 2 013 nucleotide sites. Tree topologies generated by BI and ML analyses were identical, albeit there were slight differences in statistical support for some relationships. Figure 4 shows a branch-length phylogram inferred with RAxML

with support values. The collections of *Phylloporus* in China were grouped into 31 independent species-level lineages (Fig. 4).

The combined dataset (28S + ITS) of *Pulchroboletus* included 26 taxa with 1 393 nucleotide sites. Tree topologies generated by BI and ML analyses were identical, albeit there were slight differences in statistical support for some relationships. Figure 5 shows a branch-length phylogram inferred with RAxML with support values. The collections of *Pulchroboletus* in China were grouped into one independent species-level lineage (Fig. 5).

The combined dataset (28S + ITS + *tef1*) of *Xerocomus* included 110 taxa with 2 332 nucleotide sites. Tree topologies generated by BI and ML analyses were identical, albeit there were slight differences in statistical support for some relationships. Figure 6 shows a branch-length phylogram inferred with RAxML with support values. The collections of *Xerocomus* in China were grouped into 12 independent species-level lineages (Fig. 6).

## Taxonomy

***Aureoboletus*** Pouzar, Česká Mykol. 11: 48. 1957.

*Aureoboletus*, typified by *A. gentilis*, was initially established to accommodate species with “golden yellow spores” (Pouzar 1957). Based on molecular phylogenetic evidence, the genus now includes taxa with a more diverse range of morphological features. Besides three new species described in the present study, 26 species have been confirmed to be distributed in China (Bi *et al.* 1982, Li & Song 2003, Shi & Liu 2013, Zeng *et al.* 2015, Zhang *et al.* 2014, 2015a, b, 2017, 2019a, 2022, Li *et al.* 2016, Wu *et al.* 2016, Wang *et al.* 2020).

***Aureoboletus albipes*** N.K. Zeng, Xu Zhang & Zhi Q. Liang, **sp. nov.** MycoBank MB 846902. Figs 7A–C, 9.

*Etymology*: *albipes* (Lat.), refers to the white stipe.

*Diagnosis*: Differs from other species of *Aureoboletus* by a medium to large-sized basidioma, a reddish brown, dry pileus, a brilliant yellow hymenophore surface, a white stipe, and an intricate trichodermal pileipellis composed of filamentous hyphae.

*Typus*: **China**, Fujian Province, Yong'an City, Tianbaoyan National Nature Reserve, elev. 350 m, 17 Aug. 2017, N.K. Zeng, Zeng3267 (**holotype** FHMU2228).

*Additional material examined*: **China**, Fujian Province, Yong'an City, Tianbaoyan National Nature Reserve, elev. 350 m, 17 Aug. 2017, N.K. Zeng, Zeng3276 (FHMU2237).

*Description*: *Basidiomata* medium to large-sized. *Pileus* 5.5–10 cm diam, subhemispherical when young, then convex to applanate; surface dry, submentose, slightly wrinkled, pale reddish brown (6A4), reddish brown (6A6) to brown (6B5); context white (1A1),

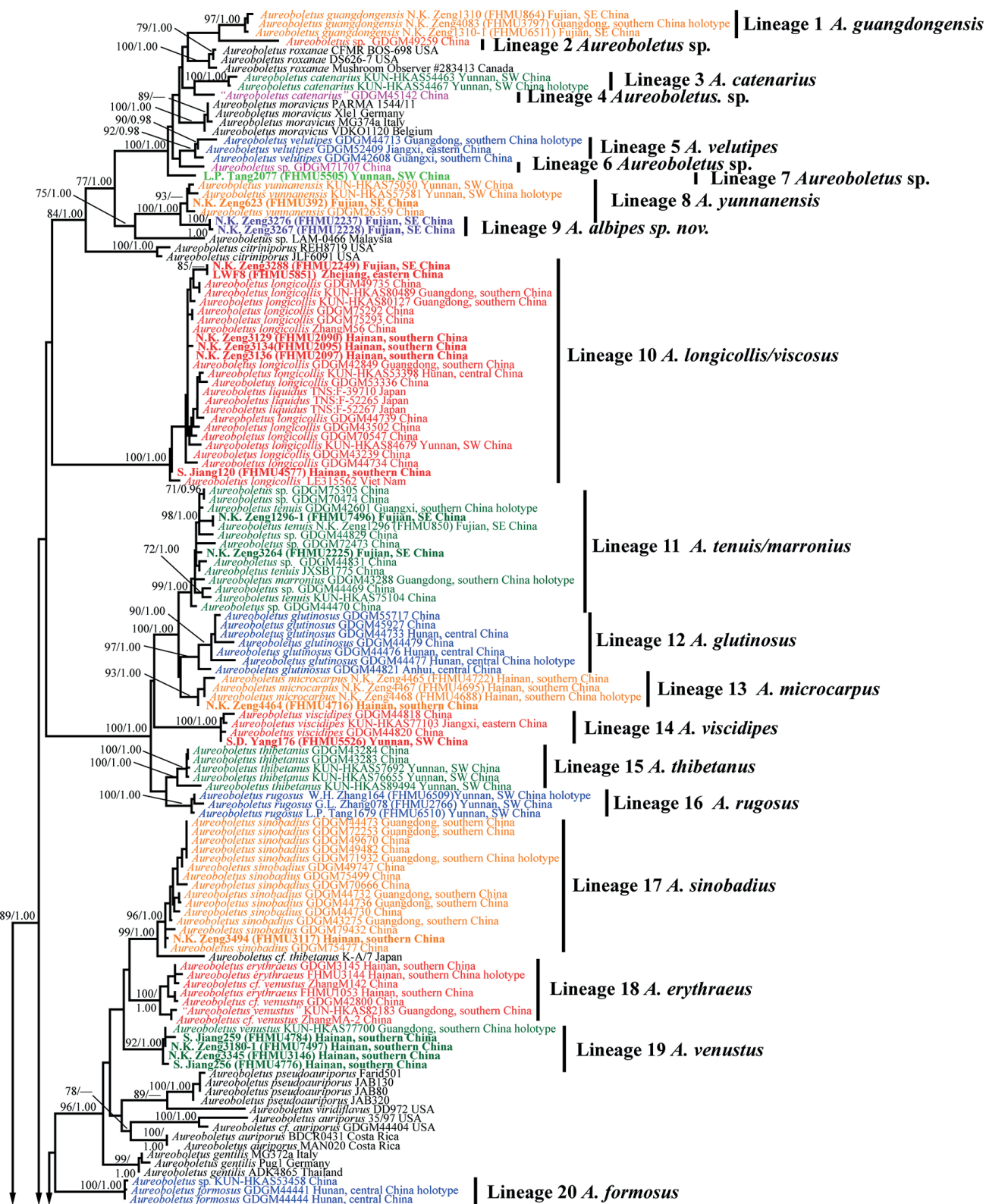
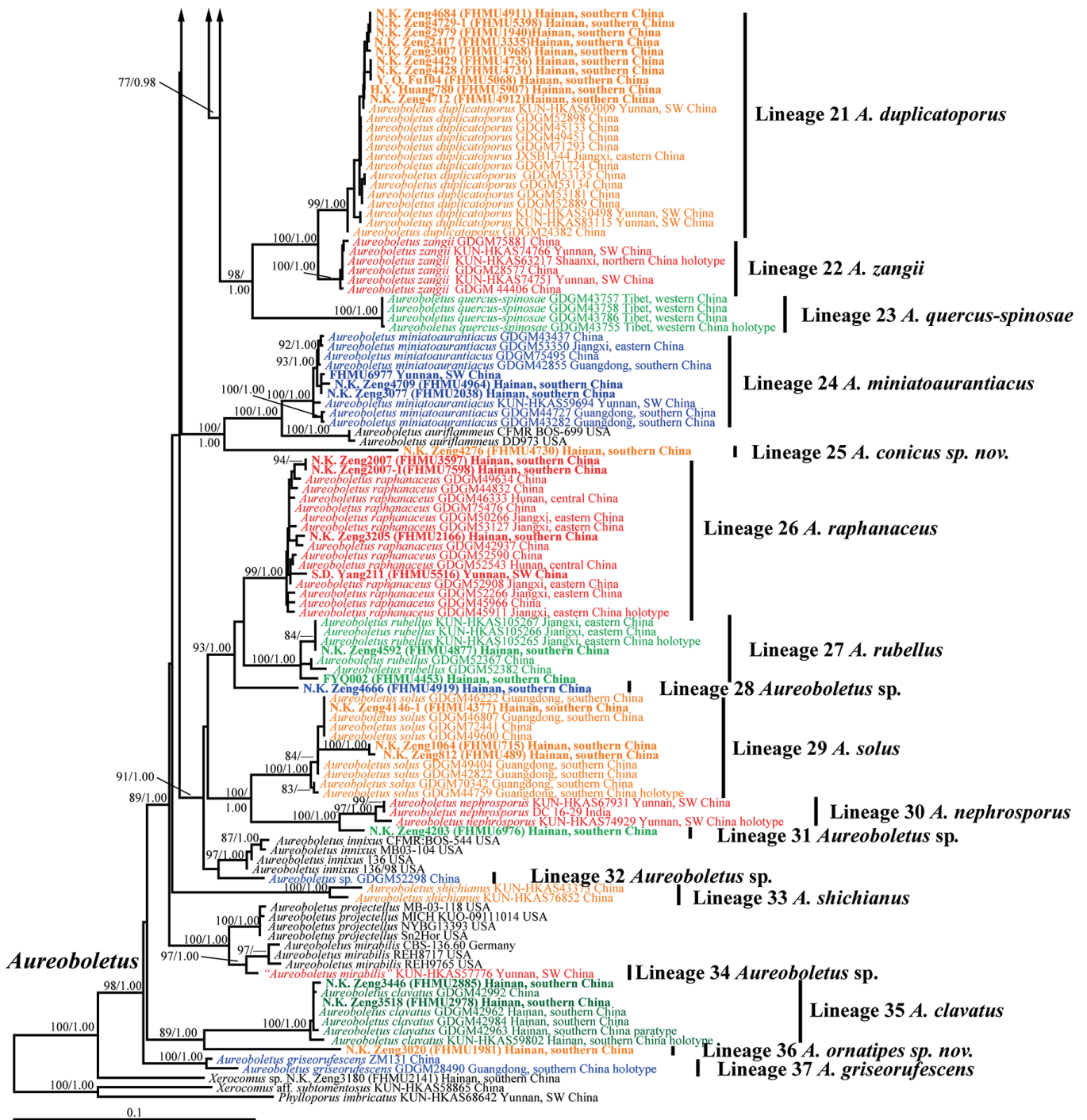


Fig. 1. Phylogram of *Aureoboletus* inferred from multilocus (28S, *tef1*, and *rpb2*) dataset using RAXML. Maximum likelihood bootstrap support values ( $\geq 70\%$ ) and PP ( $\geq 0.95$ ) are indicated above the branches. Notes: NW = northwestern, SE = southeastern, SW = southwestern; Chinese taxa/lineages are in color and newly generated sequences are in bold.

unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores angular to subround, brilliant yellow (4A5), unchanging in colour when injured; tubes 0.7–1 cm in length, yellow, unchanging in colour when injured. *Stipe* 7–11 × 1.3–3 cm, central, subcylindrical or subclavate; surface white, sometimes tinged with brownish; context white (1A1) to yellowish white (1A2), unchanging in colour when injured. *Basal mycelium* white (1A1). *Odour* indistinct.

*Basidia* 22–30 × 8–10  $\mu\text{m}$ , clavate, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ), 4-spored, hyaline or yellowish in KOH; sterigmata 3–4  $\mu\text{m}$  in length. *Basidiospores* [100/5/3] (9–)10–11(–12) × 4–4.5(–5)  $\mu\text{m}$ ,  $Q = (1.78\text{--})1.8\text{--}2.6\text{--}(2.7)$ ,  $Q_m = 2.2 \pm 0.2$ , elongate to cylindrical, slightly thick-walled (up to 1  $\mu\text{m}$ ), smooth, yellowish brown in KOH. *Cheilocystidia* 24–32 × 8–10.5  $\mu\text{m}$ , clavate to subfusiform, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ), yellowish white or hyaline in KOH. *Pleurocystidia* abundant, 30–48 × 7.5–9





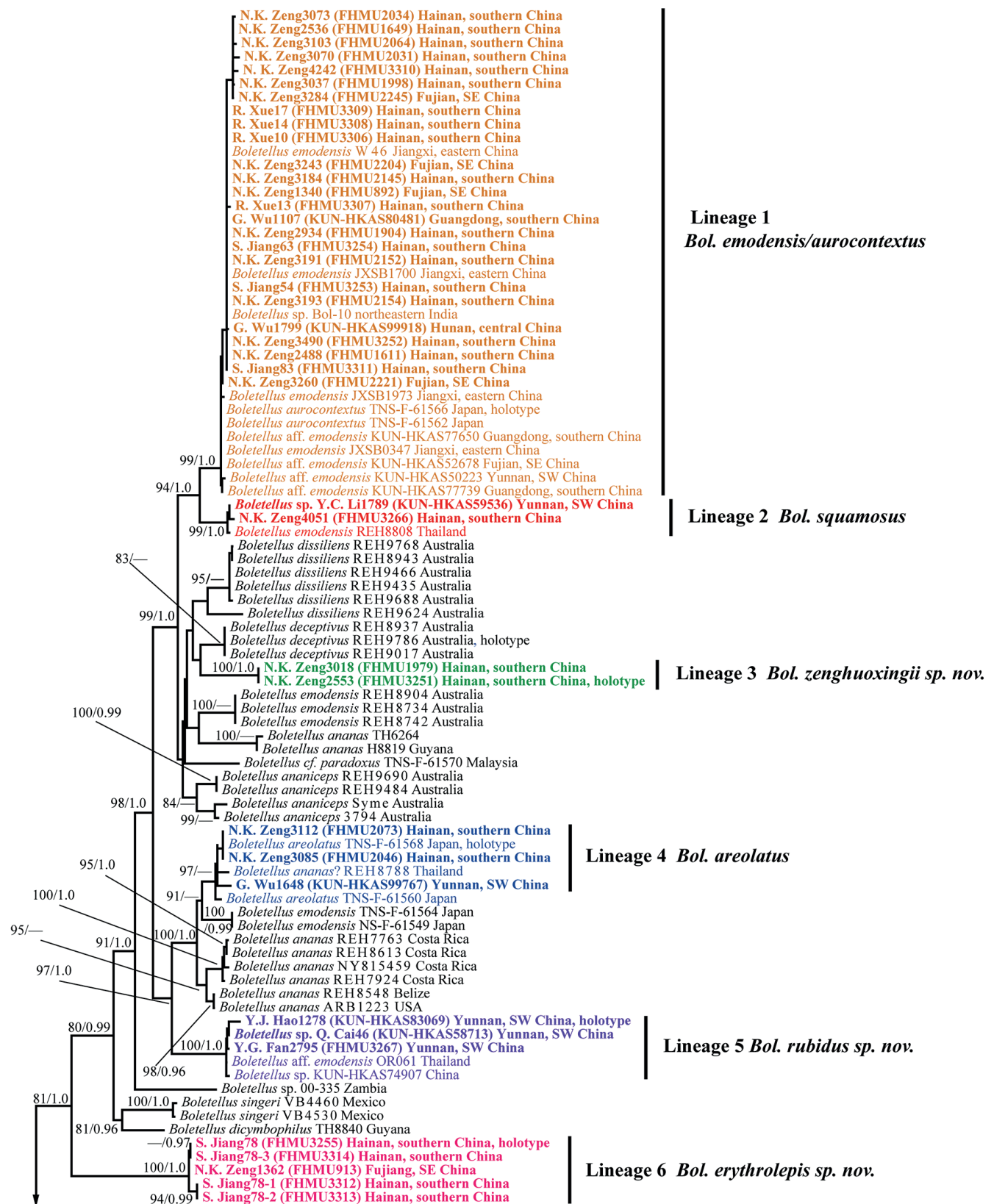
**Fig. 1. (Continued).**

µm, fusiform or subfusiform, yellowish in KOH, thin- to slightly thick-walled (up to 1 µm). *Hymenophoral trama* bilateral, composed of hyphae 4–10 µm wide, thin- to slightly thick-walled (up to 1 µm), yellowish in KOH. *Pileipellis* an intricate trichoderm 150–200 µm thick, made up of hyphae 3–7 µm diam, occasionally branched, pale yellow or hyaline in KOH; terminal cells 37–60 × 5–7 µm, subcylindrical, with obtuse apex. *Pileal trama* composed of hyphae 3–10 µm diam, slightly thick-walled (up to 1 µm), hyaline in KOH. *Stiptipellis* a trichoderm-like structure 100–250 µm thick, made up of hyphae 5–12 µm diam, thin-walled, yellowish white or hyaline in KOH; terminal cells 25–37 × 7.5–11 µm, broadly clavate, subcylindrical, or subfusiform, with obtuse apex. *Stipe trama* composed of parallel hyphae 2–8 µm wide, slightly thick-walled (up to 1 µm), hyaline in KOH. *Clamp connections* absent in all tissues.

**Habitat:** Solitary or gregarious on the ground in forests dominated by *Castanopsis kawakamii*.

*Known distribution:* Southeastern China (Fujian Province).

**Notes:** Morphologically, *A. albipes* is similar to *A. auriporus*, but, *A. auriporus* has a stipe coated at first with a pale lemon-coloured pruinosity, larger pleurocystidia measuring  $38\text{--}70 \times 9\text{--}16\text{ }\mu\text{m}$ , some hyphae in pileipellis slightly inflated, and it is distributed in North America (Smith & Thiers 1971). Phylogenetically, *A. albipes* is related to *A. yunnanensis* (Fig. 1). However, *A. yunnanensis*, originally described from Yunnan Province of southwestern China, has a pileus tinged with orange, a greyish yellow to blond stipe, wider basidiospores measuring  $9\text{--}11 \times 4\text{--}5.5\text{ }\mu\text{m}$ , and an ixotrichodermal pileipellis (Wu *et al.* 2016).



**Fig. 2.** Phylogram of *Boletellus* inferred from a multilocus (28S, *tef1*, and *rpb2*) data set using RAxML. Maximum likelihood bootstrap support values ( $\geq 70\%$ ) and PP ( $\geq 0.95$ ) are indicated above the branches. Notes: SE = southeastern, SW = southwestern; Chinese taxa/lineages are in color and newly generated sequences are in bold.

***Aureoboletus catenarius*** G. Wu & Zhu L. Yang, Fungal Diversity 81: 44. 2016. MycoBank MB 818384.

**Known distribution:** Southwestern China (Yunnan Province) (Wu *et al.* 2016).

*Holotype*: KUN-HKAS54467 (China, Yunnan Province).

Notes: *Aureoboletus catenarius* was originally described from Yunnan Province, southwestern China (Wu *et al.* 2016); illustrations and a full description of the species have been provided by Wu *et al.* (2016).



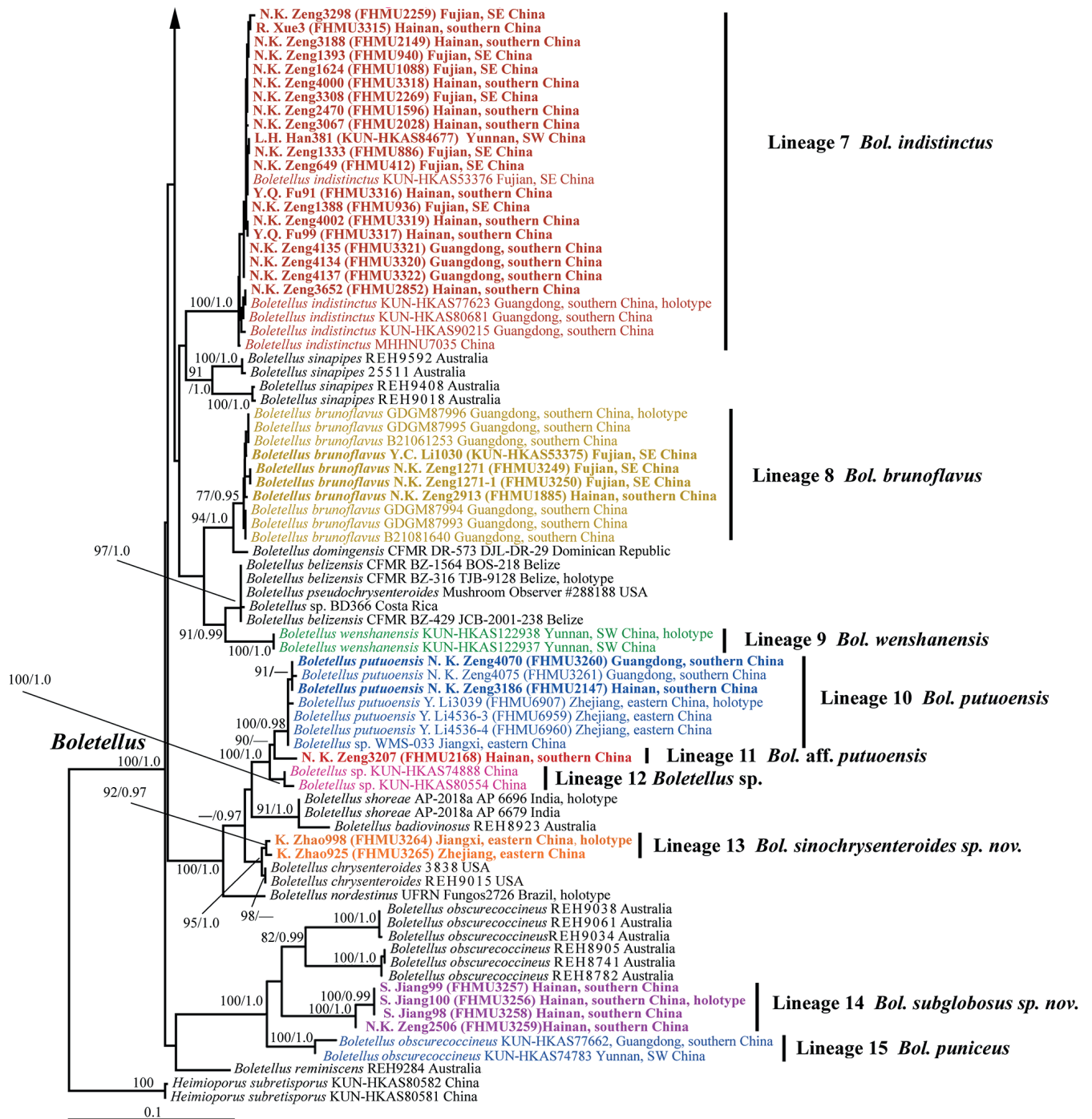


Fig. 2. (Continued).

***Aureoboletus clavatus*** N.K. Zeng & Ming Zhang, Phytotaxa 222: 132. 2015. MycoBank MB 812119.

**Known distribution:** Southern China (Hainan Province) (Zeng *et al.* 2015).

**Holotype:** KUN-HKAS59802 (China, Hainan Province).

**Materials examined:** **China**, Hainan Province, Jianfengling of Hainan Tropical Rainforest National Park, elev. 650 m, 28 Jun. 2018, N.K. Zeng, Zeng3446 (FHMU5229); Limushan of Hainan Tropical Rainforest National Park, elev. 700 m, 29 Jun. 2018, N.K. Zeng, Zeng3518 (FHMU2978).

**Notes:** *Aureoboletus clavatus* was originally described from Hainan Province, southern China (Zeng *et al.* 2015); illustrations and a

full description of the species have been provided by Zeng *et al.* (2015).

***Aureoboletus conicus*** N.K. Zeng, Xu Zhang & Zhi Q. Liang, *sp. nov.* MycoBank MB 846903. Figs 7D, E, 10.

**Etymology:** *conicus* (Lat.), refers to the conical squamules on pileus.

**Diagnosis:** Differs from other species of *Aureoboletus* by a small basidioma, an orangish brown, dry pileus densely covered with brown, small, conical squamules, a pale yellow hymenophore surface, and smaller basidiospores measuring 7–9 × 4–5.5 µm.



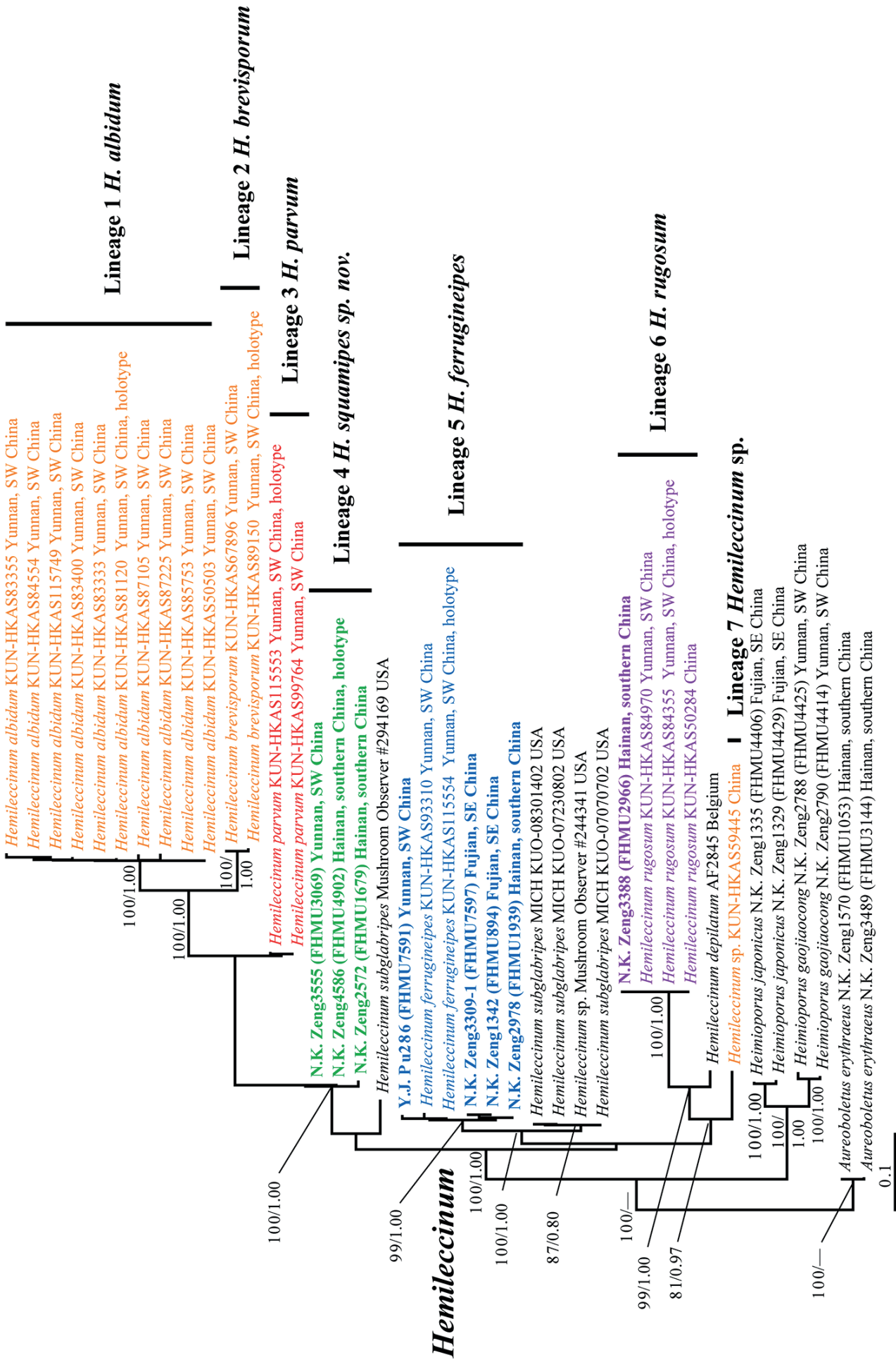


Fig. 3. Phylogram of *Hemileccinum* inferred from a three-locus (28S, ITS regions, and *tef1*) dataset using RAxML. Maximum likelihood bootstrap support values ( $\geq 70\%$ ) and PP ( $\geq 0.95$ ) are indicated above the branches. Notes: SE = southeastern, SW = southwestern; Chinese taxa/lineages are in color and newly generated sequences are in bold.

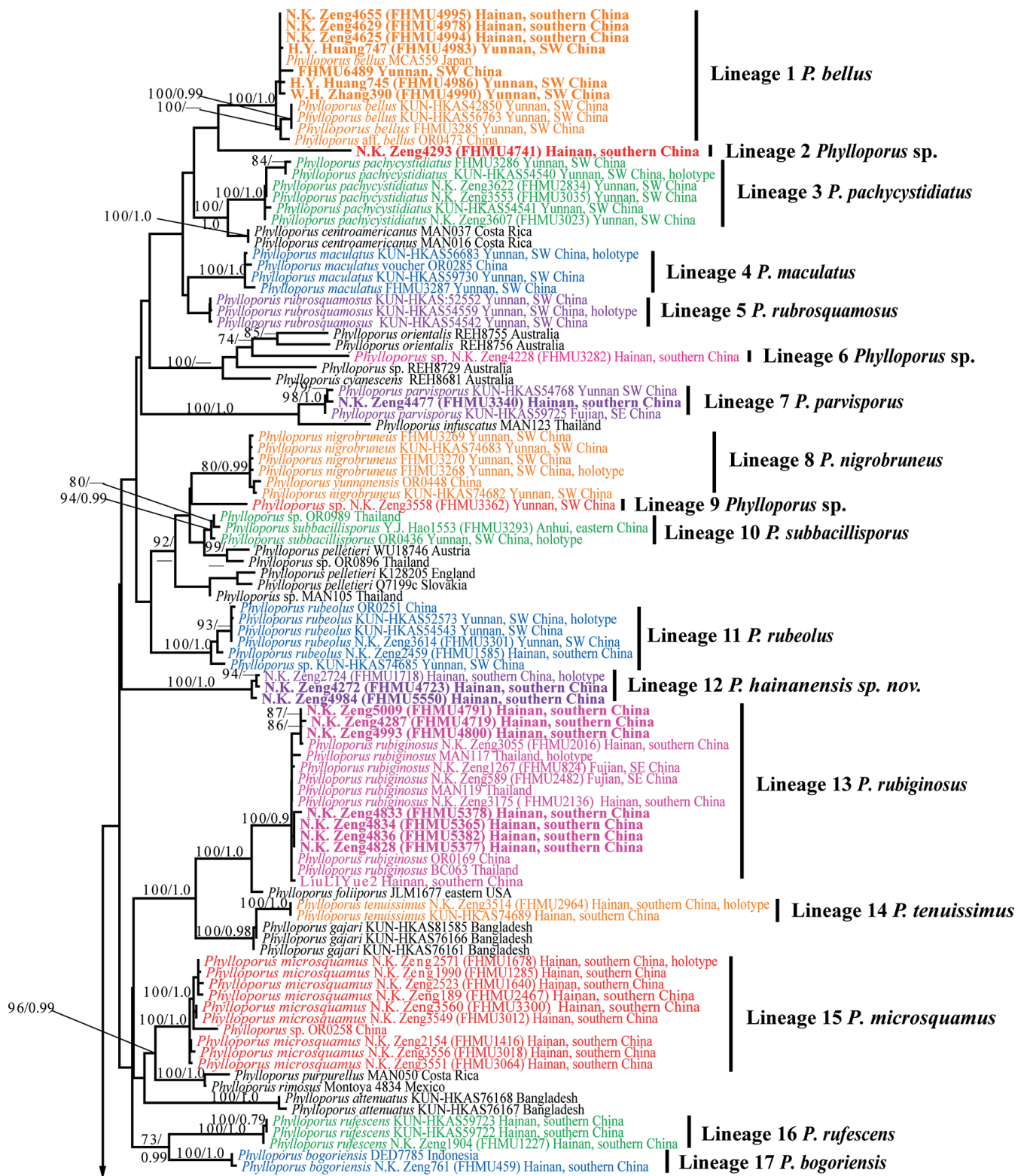


Fig. 4. Phylogram of *Phylloporus* inferred from a three-locus (28S, ITS regions, and *tef1*) dataset using RAxML. Maximum likelihood bootstrap support values ( $\geq 70\%$ ) and PP ( $\geq 0.95$ ) are indicated above the branches. Notes: SE = southeastern, SW = southwestern; Chinese taxa/lineages are in color and newly generated sequences are in bold.

**Typus:** China, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 550 m, 2 Jul. 2020, N.K. Zeng, Zeng4276 (**holotype** FHMU4730).

**Description:** *Basidiomata* small-sized. *Pileus* 2.6–3.3 cm diam, convex to nearly plane, surface dry, orangish brown (6C4), densely covered with brown, small, conical squamules; context whitish (1A1), unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores about 0.3 mm diam, angular,

pale yellow (4A2), unchanging in colour when injured; tubes about 3 mm in length, white (1A1), unchanging in colour when injured. *Stipe* 3.5–6 × 1 cm, central, subcylindrical or subclavate; surface white, densely covered with pale orangish brown (6B2) squamules; context brownish white (6B2), unchanging in colour when injured. *Odour* indistinct.

*Basidia* 22–30 × 7–10 µm, clavate, thin- to slightly thick-walled (up to 1 µm), 4-spored, hyaline or yellowish in KOH; sterigmata



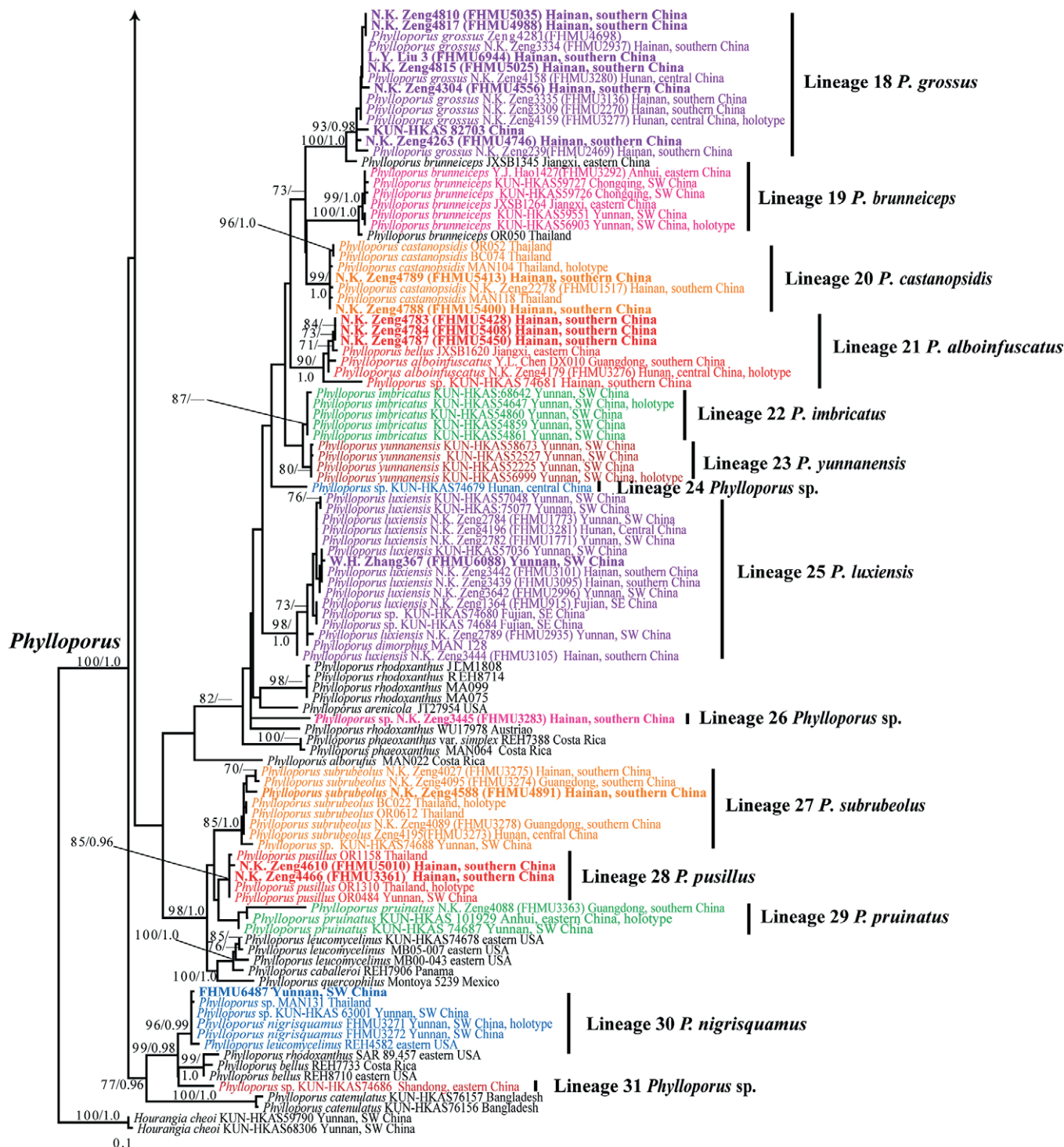


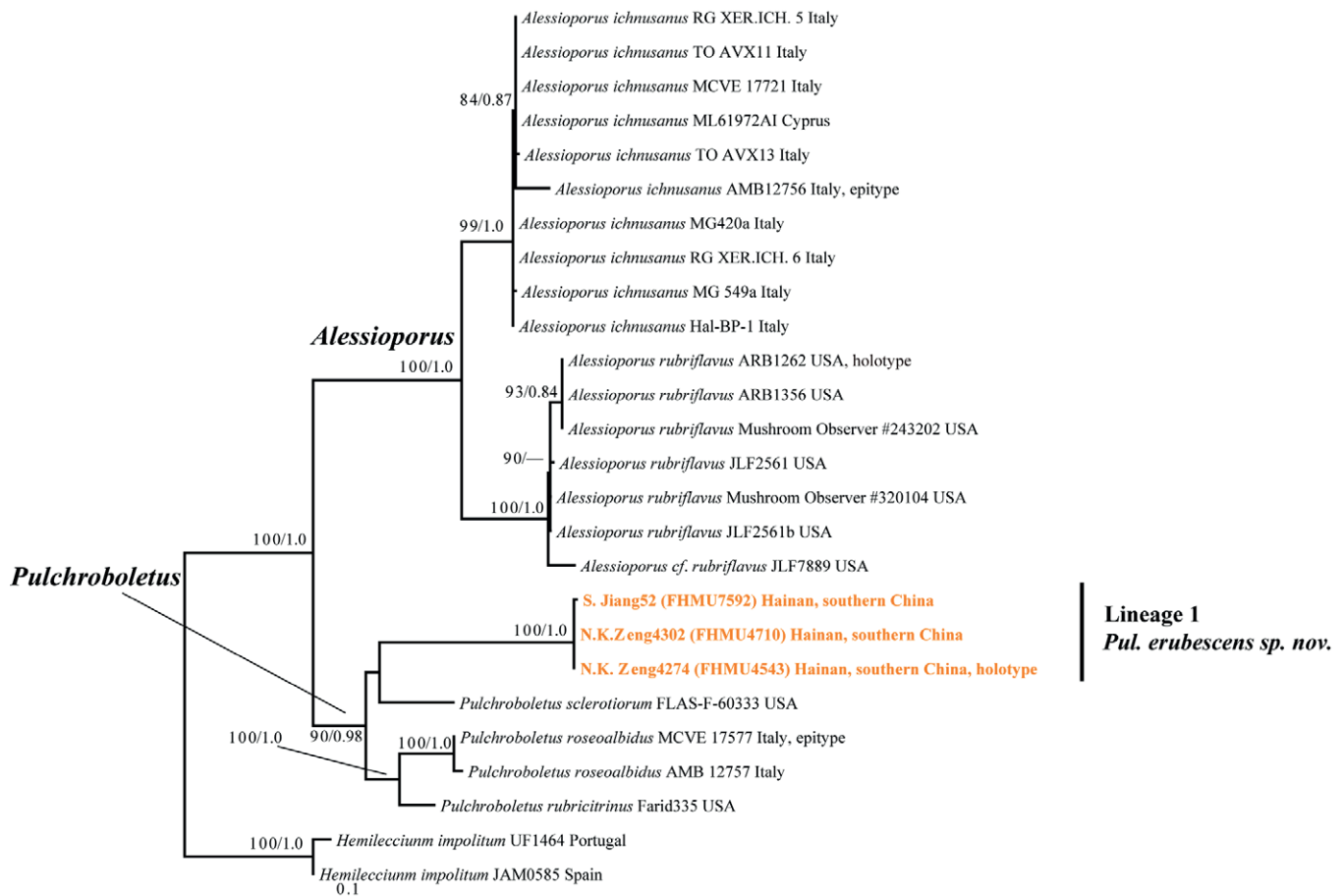
Fig. 4. (Continued).

3–4  $\mu\text{m}$  in length. *Basidiospores* [20/1/1] (6–)7–9(–9.5)  $\times$  4–5.5(–6)  $\mu\text{m}$ ,  $Q = 1.17$ –1.7(–1.78),  $Q_m = 1.51 \pm 0.16$ , broadly ellipsoid to ellipsoid, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ), smooth, brownish yellow in KOH. *Cheilocystidia* 25–30  $\times$  8–9  $\mu\text{m}$ , subfusiform or subclavate, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ), yellowish in KOH. *Pleurocystidia* 30–35  $\times$  8–11  $\mu\text{m}$ , fusoid-ventricose or subclavate, yellowish in KOH, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ). *Hymenophoral trama* bilateral, composed of hyphae 5–10  $\mu\text{m}$  wide, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ), yellowish in KOH. *Pileipellis* a trichoderm 200–300  $\mu\text{m}$  thick, made up of hyphae 5–13  $\mu\text{m}$  diam, yellowish in KOH; terminal cells 26–37  $\times$  8–11  $\mu\text{m}$ , subclavate or subcylindrical, with obtuse apex; *Pileal trama*

composed of hyphae 3–10  $\mu\text{m}$  diam, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ), hyaline in KOH. *Stipitipellis* a trichoderm-like structure 400–600  $\mu\text{m}$  thick, made up of hyphae 5–10  $\mu\text{m}$  diam, thin-walled, brownish yellow in KOH; terminal cells 26–31  $\times$  5–6  $\mu\text{m}$ , broadly clavate, subcylindrical, or subfusiform, with obtuse apex. *Stipe trama* composed of parallel hyphae 5–15  $\mu\text{m}$  wide, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ), yellowish in KOH. *Clamp connections* absent in all tissues.

*Habitat*: Solitary on the ground in forests dominated by fagaceous trees.





**Fig. 5.** Phylogram of *Pulchroboletus* inferred from a two-locus (28S and ITS) dataset using RAxML. Maximum likelihood bootstrap support values ( $\geq 70\%$ ) and PP ( $\geq 0.95$ ) are indicated above the branches. Notes: SE = southeastern, SW = southwestern; Chinese taxon/lineage is in color and newly generated sequences are in bold.

**Known distribution:** Southern China (Hainan Province).

**Notes:** *Aureoboletus conicus* is morphologically similar to *A. duplicatoporus* and *A. innixus*. However, *A. duplicatoporus*, originally described from Yunnan Province of southwestern China, has a larger pileus (up to 9 cm diam) with a nearly glabrous surface, a bright yellow hymenophore with compound pores, longer basidiospores measuring  $8.5\text{--}10.5 \times 4\text{--}5.5\ \mu\text{m}$ , and an ixotrichodermium-type pileipellis (see below). *Aureoboletus innixus* has a larger basidioma (pileus up to 7.5 cm diam), a pileal surface somewhat velvety, frequently cracked in age, a bright yellow hymenophore surface when young, longer and narrower basidiospores measuring  $8\text{--}11 \times 3\text{--}5\ \mu\text{m}$ , and it is distributed in North America (Bessette *et al.* 2016). Phylogenetically, *A. conicus* is closely related to *A. auriflammeus* and *A. miniatoaurantiacus* (Fig. 1). However, *A. auriflammeus*, originally described from USA, has a tomentose or pulverulent pileus without conical squamules, a dark yellow to orange hymenophore, and longer and narrower basidiospores measuring  $9\text{--}10 \times 3\text{--}4\ \mu\text{m}$  (García-Jiménez *et al.* 2019); *A. miniatoaurantiacus*, originally described from Guangdong Province of southern China (Zhang *et al.* 2019a), has a tomentose or pulverous, orangish yellow to orange pileus without conical squamules, and an orangish yellow to orange stipe (see below).

***Aureoboletus duplicatoporus*** (M. Zang) G. Wu & Zhu L. Yang, Fungal Diversity 81: 44. 2016. MycoBank MB 818385. Figs 7F, G, 11.

**Basionym:** *Sinoboletus duplicatoporus* M. Zang, Mycotaxon 45: 224. 1992.

**Synonym:** *Sinoboletus gelatinosus* M. Zang & R.H. Petersen, Acta Bot. Yunnan. 26: 625. 2004.

**Description:** Basidiomata small to medium-sized. *Pileus* 2–9 cm diam, subhemispherical when young, then convex to applanate; surface subtomentose, viscid, reddish brown when young, then brown; context white, unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores compound, 0.1–0.15 cm diam, angular to subround, bright yellow, unchanging in colour when injured; tubes about 0.5 cm in length, pale yellow, unchanging in colour when injured. *Stipe* 3–6.5  $\times$  0.9–1.6 cm, central, subcylindrical, or subclavate; surface pale brownish red when young, then pastel reddish violet, viscid when wet; context white, sometimes tinged with reddish, unchanging in colour when injured. *Basal mycelium* white. *Odour* indistinct.

*Basidia* 25–40  $\times$  7.5–9  $\mu\text{m}$ , clavate, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ), 4-spored, hyaline or yellowish in KOH; sterigmata 5–8.5  $\mu\text{m}$  in length. *Basidiospores* [80/4/4] (7–)8.5–10.5(–12)  $\times$  4–5.5  $\mu\text{m}$ ,  $Q = (1.4\text{--})1.5\text{--}2.2(\text{--}2.6)$ ,  $Q_m = 1.89 \pm 0.23$ , ellipsoid to cylindrical, slightly thick-walled (up to 1  $\mu\text{m}$ ), smooth, yellowish in KOH. *Cheilocystidia* 53–65  $\times$  11–15  $\mu\text{m}$ , fusoid-ventricose to clavate, thin- to thick-walled (up to 1.5  $\mu\text{m}$ ), yellowish white or hyaline in KOH. *Pleurocystidia* 35–68  $\times$  10–20.5  $\mu\text{m}$ , abundant, fusoid-ventricose, yellowish in KOH, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ). *Hymenophoral trama* bilateral, composed of hyphae 4–13  $\mu\text{m}$  wide, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ), yellowish in KOH. *Pileipellis* an ixotrichoderm 500–800  $\mu\text{m}$  thick, made up of hyphae 3–17  $\mu\text{m}$  diam, occasionally branched, yellowish white or hyaline in KOH; terminal cells 22–50  $\times$  8–16.5  $\mu\text{m}$ , subclavate or



**Fig. 6.** Phylogram of *Xerocomus* inferred from multilocus (28S, ITS regions, and *tef1*) dataset using RAXML. Maximum likelihood bootstrap support values ( $\geq 70\%$ ) and PP ( $\geq 0.95$ ) are indicated above the branches. Notes: SE = southeastern, SW = southwestern; Chinese taxa/lineages are in color and newly generated sequences are in bold.

subcylindrical, with obtuse apex. *Pileal trama* composed of hyphae 2–7  $\mu\text{m}$  diam, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ), hyaline in KOH. *Stipitipellis* is a trichoderm-like structure 400–700  $\mu\text{m}$  thick, made up of hyphae 3–11  $\mu\text{m}$  diam, thin-walled, hyaline in KOH; terminal cells 25–50  $\times$  3.5–10  $\mu\text{m}$ , broadly clavate, subcylindrical, or subfusiform, with obtuse apex. *Stipe trama* composed of parallel hyphae 3–15  $\mu\text{m}$  wide, thin- to thick-walled (up to 1.5  $\mu\text{m}$ ), hyaline in KOH. *Clamp connections* absent in all tissues.

**Habitat:** Solitary on the ground in forests dominated by fagaceous trees.

**Known distribution:** Southern (Hainan Province) and southwestern China (Yunnan Province) (Wu *et al.* 2016).

**Holotype:** KUN-HKAS23687 (China, Yunnan Province).

**Materials examined:** China, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 520 m, 31 Jul. 2015, N.K. Zeng, Zeng2417

(FHMU3335); same location, 26 May 2017, N.K. Zeng, Zeng2979 (FHMU1940); same location, 27 May 2017, N.K. Zeng, Zeng3007 (FHMU1968); same location, 13 Aug. 2020, N.K. Zeng, Zeng4712 (FHMU4912).

**Notes:** *Aureoboletus duplicatoporus* was described from Yunnan Province, southwestern China by Zang (1992), and subsequently reported from Hainan Province, tropical China (Zeng & Jiang 2020). It was first classified in the genus *Sinoboletus* but was later transferred to *Aureoboletus* by Wu *et al.* (2016). The species is characterised by a small to medium-sized basidioma, a viscid, reddish brown to brown pileus, bright yellow, compound pores, a viscid, pale brownish red to pastel reddish violet stipe, and an ixotrichodermal pileipellis composed of mostly inflated hyphae.

***Aureoboletus erythraeus*** N.K. Zeng *et al.*, Phytotaxa 472: 101. 2020. MycoBank MB 835947.

**Known distribution:** Southern China (Hainan Province) (Wang *et al.* 2020).

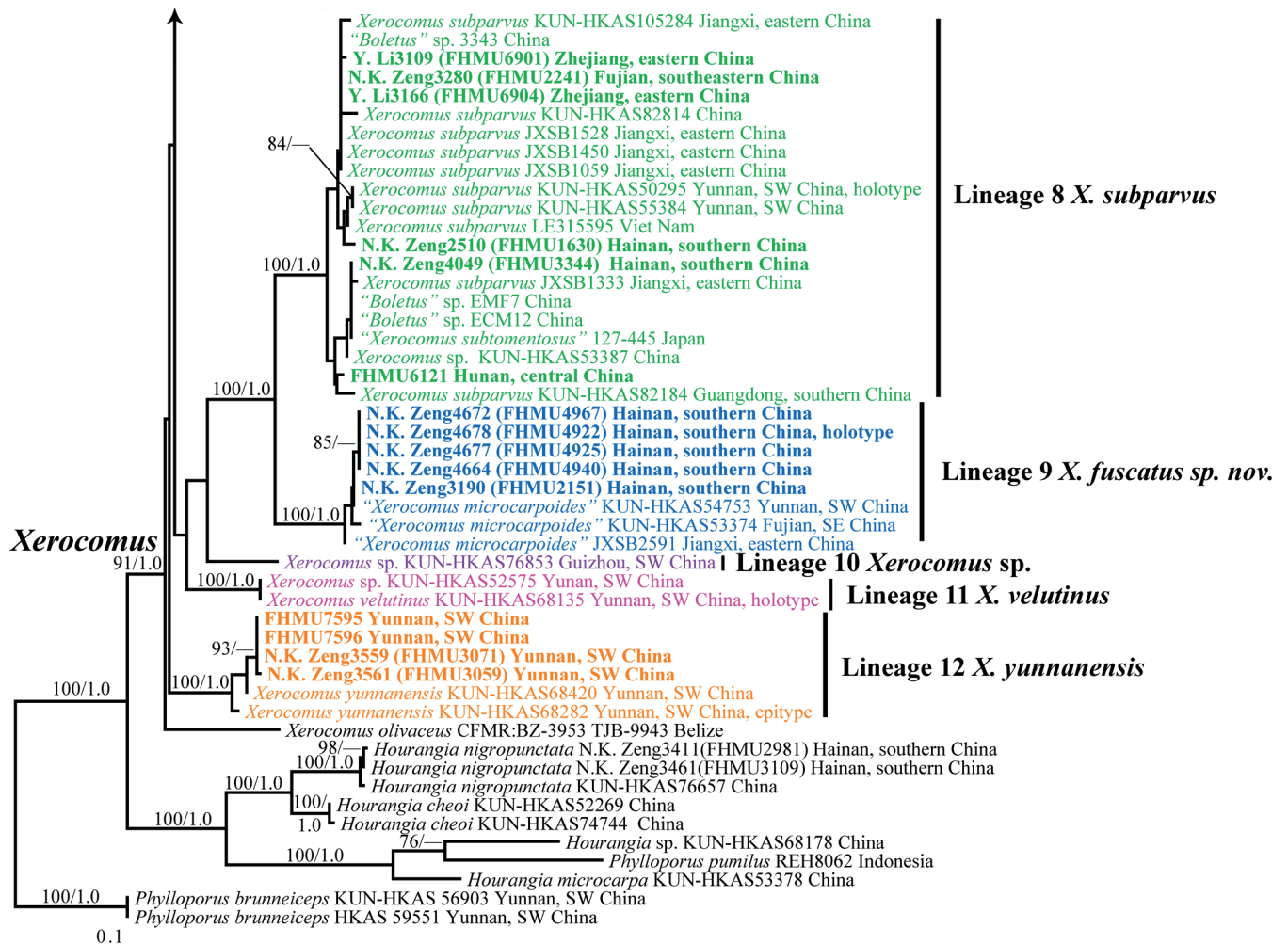


Fig. 6. (Continued).

*Holotype*: FHMU3144 (China, Hainan Province).

*Notes*: *Aureoboletus erythraeus* was originally described from Hainan Province, southern China (Wang *et al.* 2020); illustrations and a full description of the species have been provided by Wang *et al.* (2020).

***Aureoboletus formosus*** Ming Zhang & T.H. Li, Mycol. Progr. 14: 118. 2015. MycoBank MB 813630.

*Known distribution*: Central China (Hunan Province) (Zhang *et al.* 2015a).

*Holotype*: GDGM44441 (China, Hunan Province).

*Notes*: *Aureoboletus formosus* was originally described from Hunan Province, central China (Zhang *et al.* 2015a); illustrations and a full description of the species have been provided by Zhang *et al.* (2015a).

***Aureoboletus glutinosus*** Ming Zhang & T.H. Li, MycoKeys 61: 121. 2019. MycoBank MB 827103.

*Known distribution*: Central (Hunan Province) and eastern China (Anhui Province) (Zhang *et al.* 2019a).

*Holotype*: GDGM44477 (China, Hunan Province).

*Notes*: *Aureoboletus glutinosus* was originally described from Hunan Province, central China (Zhang *et al.* 2019a); illustrations and a full description of the species have been provided by Zhang *et al.* (2019a).

***Aureoboletus griseorufescens*** Ming Zhang & T.H. Li, MycoKeys 61: 124. 2019. MycoBank MB 827104.

*Known distribution*: Southern China (Guangdong and Hainan Provinces) (Zhang *et al.* 2019a).

*Holotype*: GDGM28490 (China, Guangdong Province).

*Notes*: *Aureoboletus griseorufescens* was originally described from Guangdong Province, southern China (Zhang *et al.* 2019a). Illustrations and a full description of the species have been provided by Zhang *et al.* (2019a).

***Aureoboletus guangdongensis*** N.K. Zeng *et al.*, Phytotaxa 567: 139. 2022. MycoBank MB 841618.

*Known distribution*: Southern (Guangdong Province) and southeastern China (Fujian Province) (Zhang *et al.* 2022).

*Holotype*: FHMU3797 (China, Guangdong Province).





Fig. 7. Basidiomata of *Aureoboletus* species. A–C. *A. albipes* (A. holotype FHMU2228; B, C. FHMU2237). D, E. *A. conicus* (holotype FHMU4730). F, G. *A. duplicatoporus* (F. FHMU4912; G. FHMU5398). H, I. *A. miniatoaurantiacus* (H. FHMU4964; I. FHMU2038). J–L. *A. ornatipes* (holotype FHMU1981). Photos by N.K. Zeng.

Notes: *Aureoboletus guangdongensis* was originally described from Guangdong Province, southern China (Zhang *et al.* 2022). Illustrations and a full description of the species have been provided by Zhang *et al.* (2022).

*Aureoboletus longicollis* (Ces.) N.K. Zeng & Ming Zhang, Phytotaxa 222: 133. 2015. MycoBank MB 812120.

*Basionym*: *Boletus longicollis* Ces., Atti dell'Accademia di Scienze Fisiche e Matematiche Napoli 8: 4. 1879.

*Synonyms*: *Suillus longicollis* (Ces.) Kuntze, Revis. gen. pl. (Leipzig) 3: 535. 1898.

*Boletellus longicollis* (Ces.) Pegler & T.W.K. Young, Trans. Brit.





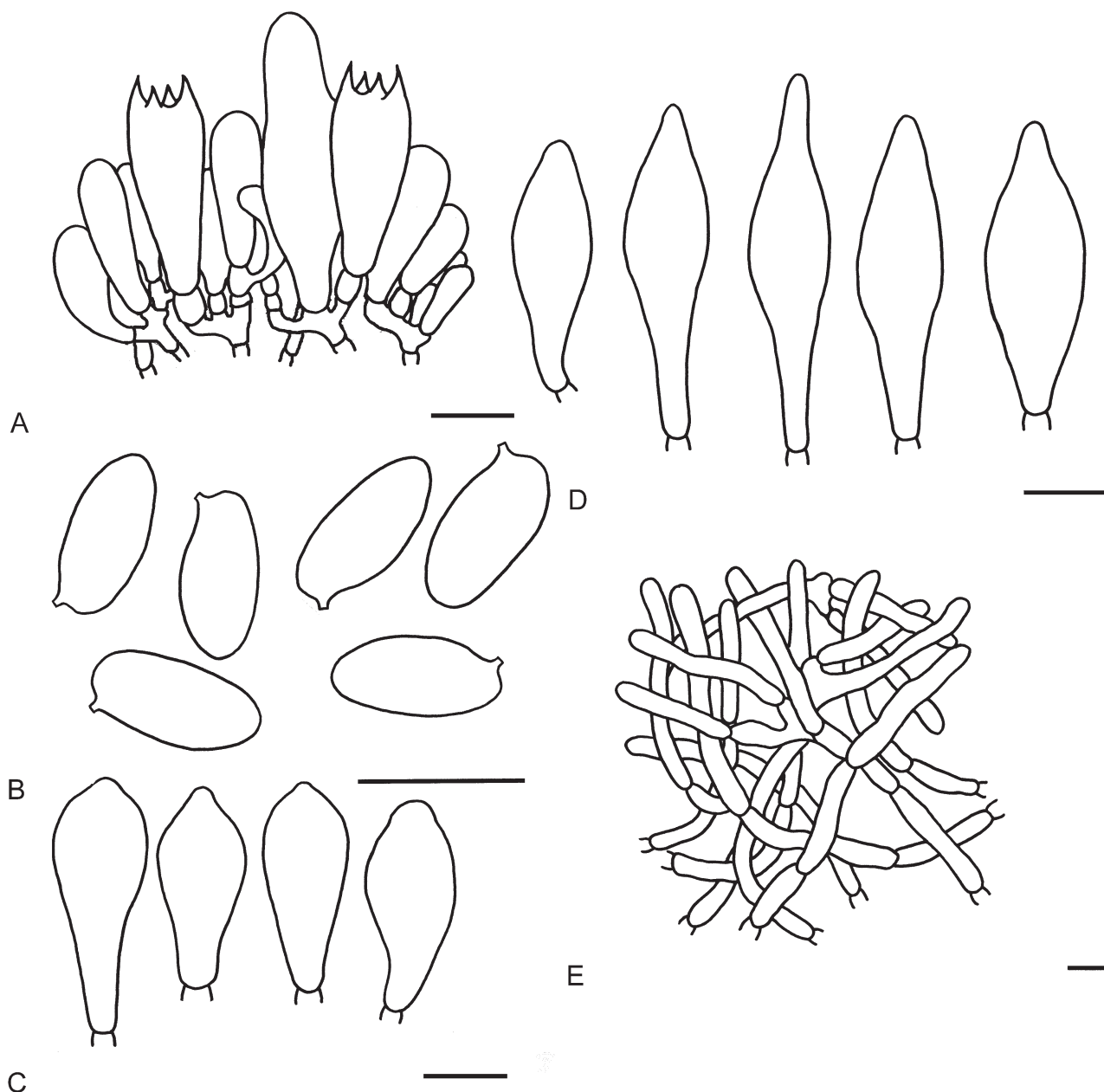
Fig. 8. Basidiomata of *Aureoboletus* species. A, B. *A. raphanaceus* (FHMU2166). C, D. *A. sinobadius* (FHMU3117). E, F. *A. solus* (FHMU3750). G–I. *A. tenuis* (G. FHMU7496; H, I. FHMU2225). J, K. *A. viscidipes* (FHMU5526). L. *A. yunnanensis* (FHMU392). Photos by N.K. Zeng.

Mycol. Soc. 76: 115. 1981.

*Aureoboletus longicollis* (Ces.) Har. Takah. & Taneyama, The fungal flora in southwestern Japan Agarics and boletes 1: 19. 2016.

*Known distribution:* Southern (Hainan and Guangdong Provinces), southeastern (Fujian Province), and eastern China (Zhejiang Province); Malaysia, Singapore, Japan, and Vietnam (Zeng *et al.* 2015, Pham & Morozova 2020).





**Fig. 9.** Microscopic features of *Aureoboletus albipes* (holotype FHMU2228). **A.** Basidia and pleurocystidium. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. Scale bars = 10 µm. Drawings by X. Zhang.

**Materials examined:** **China**, Hainan Province, Limushan of Hainan Tropical Rainforest National Park, elev. 750 m, 27 Jul. 2017, N.K. Zeng, Zeng3129, 3134, 3136 (FHMU2090, 2095, 2097); Fujian Province, Zhangping City, Tiantai National Forest Park, elev. 370 m, 18 Aug. 2017, N.K. Zeng, Zeng3288 (FHMU2249).

**Notes:** *Aureoboletus longicollis* was first described from Malaysia, then reported from Singapore, Japan, China, and Vietnam (Cesati 1879, Corner 1972, Bi *et al.* 1997, Nagasawa 1997, Halling & Ortiz-Santana 2009, Horak 2011, Pham & Morozova 2020). It was first classified in the genus *Boletus* (Cesati 1879), but was later transferred to *Boletellus* for the basidiospores with longitudinal ridges (Pegler & Young 1981). One recent study indicated it is a member of *Aureoboletus* (Zeng *et al.* 2015). Illustrations and a full description of the species have been provided by Corner (1972) and Zeng *et al.* (2015). The species is common in subtropical and tropical China (Zeng *et al.* 2015).

***Aureoboletus microcarpus*** N.K. Zeng *et al.*, Phytotaxa 567: 140. 2022. MycoBank MB 841621.

**Known distribution:** Southern China (Hainan Province) (Zhang *et al.* 2022).

**Holotype:** FHMU4688 (China, Hainan Province).

**Material examined:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 550 m, 3 Jul. 2020, N.K. Zeng, Zeng4464 (FHMU4716).

**Notes:** *Aureoboletus microcarpus* was originally described from Hainan Province, southern China (Zhang *et al.* 2022). Illustrations and a full description of the species have been provided by Zhang *et al.* (2022).

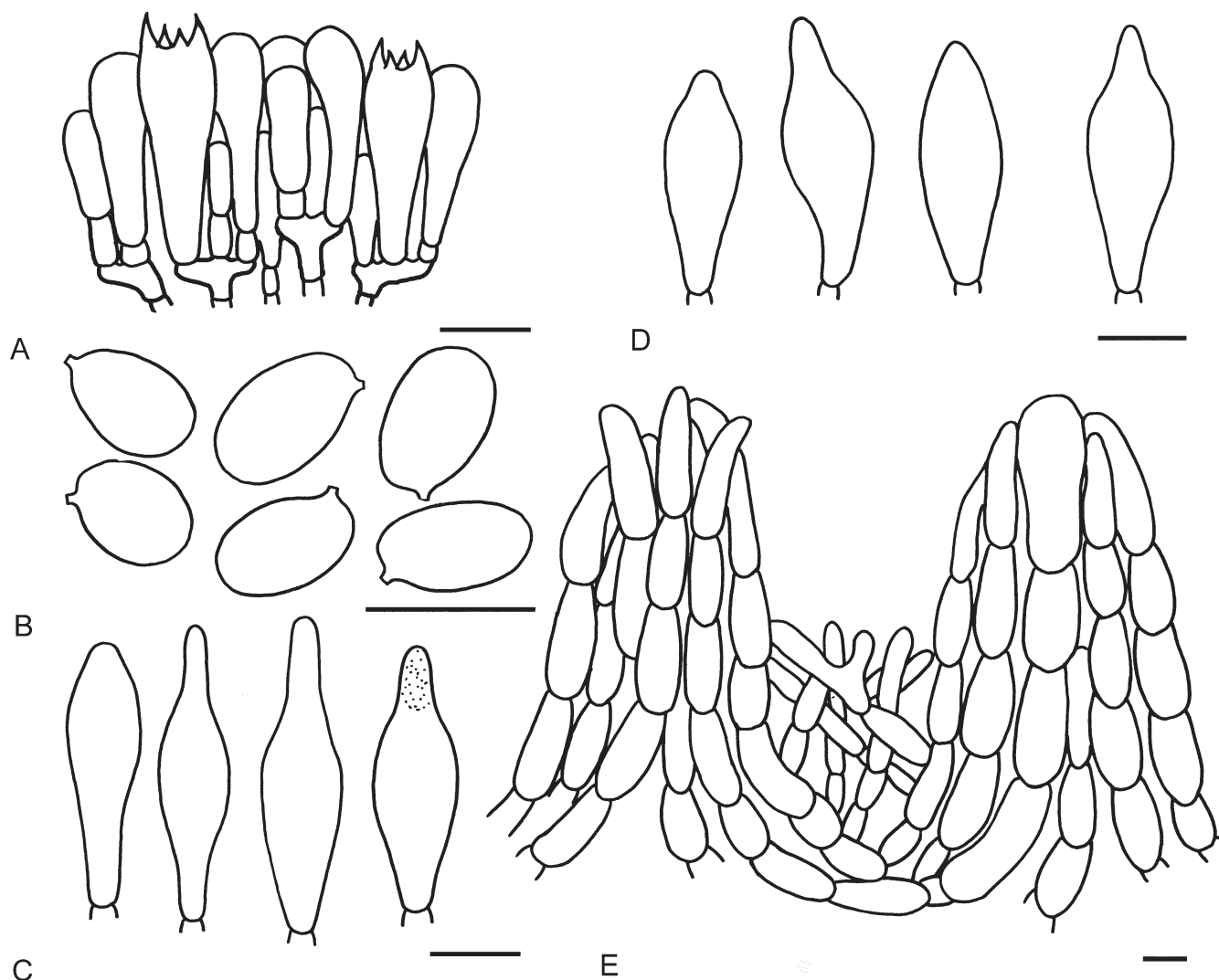


Fig. 10. Microscopic features of *Aureoboletus conicus* (holotype FHMU4730). A. Basidia. B. Basidiospores. C. Cheilocystidia. D. Pleurocystidia. E. Pileipellis. Scale bars = 10 µm. Drawings by X. Zhang.

***Aureoboletus miniatoaurantiacus*** (Bi & Loh) Ming Zhang *et al.*, Mycokeys 61: 134. 2019. MycoBank MB 827109. Figs 7H, I, 12.

*Basionym:* *Boletus miniatoaurantiacus* C.S. Bi & Loh, in Bi *et al.*, Acta Bot. Yunnan. 4: 60. 1982.

*Synonym:* *Aureoboletus tomentosus* G. Wu & Zhu L. Yang, Fungal Diversity 81: 51. 2016.

**Description:** *Basidiomata* small to medium-sized. *Pileus* 2.6–8 cm diam, subhemispherical when young, then convex to applanate; surface tomentose or pulverous, slightly wrinkled, yellowish orange to orange; context white, unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores angular, 0.5–1 mm, yellowish, unchanging in colour when injured; tubes 0.5–1 cm in length, pale yellow, unchanging in colour when injured. *Stipe* 3–5.5 × 0.3–0.8 cm, central, subcylindrical or subclavate; surface orangish yellow to orange; context white, unchanging in colour when injured. *Basal mycelium* white. *Odour* indistinct.

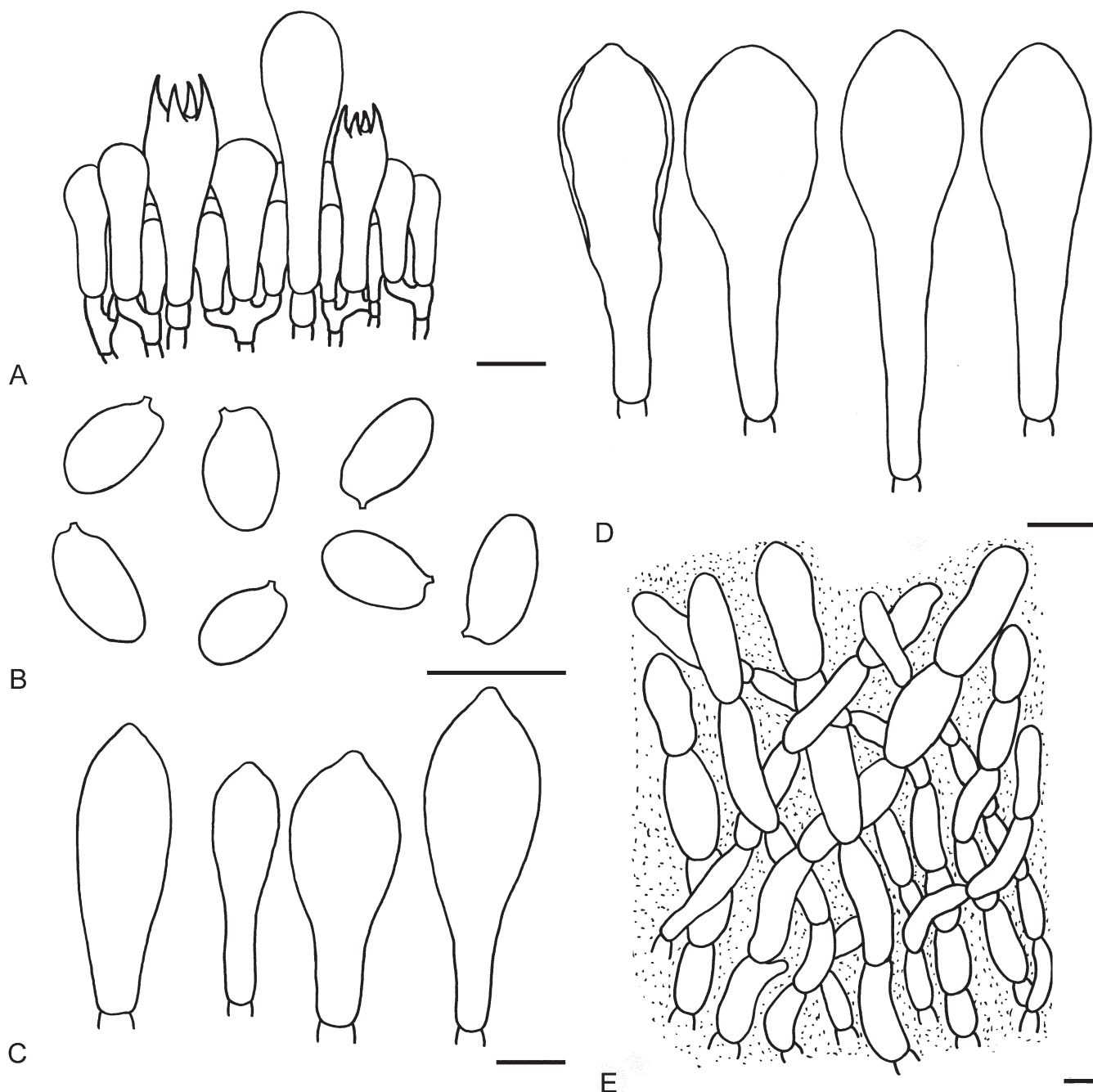
*Basidia* 32–40 × 10.5–13 µm, clavate, thin- to slightly thick-walled (up to 1 µm), 4-spored, hyaline or yellowish in KOH; sterigmata 3.5–5 µm in length. *Basidiospores* [140/7/2] 7–9(–10) × 4.5–5.5(–6) µm,  $Q = 1.4\text{--}1.8(-2)$ ,  $Q_m = 1.6 \pm 0.13$ , ovoid, slightly thick-walled (up to 1 µm), smooth, olive brown to yellowish brown in KOH. *Cheilocystidia* 42–56 × 10–15 µm, fusoid-ventricose

to clavate, thin- to slightly thick-walled (up to 1.5 µm), yellowish white or hyaline in KOH. *Pleurocystidia* 50–60 × 10–15 µm, fusoid-ventricose, yellowish in KOH, thin- to slightly thick-walled (up to 1 µm). *Hymenophoral trama* bilateral, composed of hyphae 5–10 µm wide, thin- to slightly thick-walled (up to 1 µm), yellowish in KOH. *Pileipellis* a trichoderm 250–350 µm thick, made up of hyphae 6–13 µm diam, occasionally branched, yellowish white or hyaline in KOH; terminal cells 35–55 × 8–11 µm, subclavate or subcylindrical, with obtuse apex. *Pileal trama* composed of hyphae 2–7 µm diam, slightly thick-walled (up to 1 µm), hyaline in KOH. *Stipitipellis* a trichoderm-like structure 150–250 µm thick, made up of hyphae 3–27 µm diam, thin-walled, hyaline in KOH; terminal cells 15–27 × 5–6 µm, broadly clavate, subcylindrical, or subfusiform, with obtuse apex. *Stipe trama* composed of parallel hyphae 5–10 µm wide, thin- to slightly thick-walled (up to 1 µm), hyaline in KOH. *Clamp connections* absent in all tissues.

**Habitat:** Solitary or gregarious on the ground in forests dominated by fagaceous trees.

**Known distribution:** Eastern (Jiangxi Province), southeastern (Fujian Province), southern (Hainan and Guangdong Provinces), and southwestern China (Yunnan Province) (Wu *et al.* 2016, Zhang *et al.* 2019a).





**Fig. 11.** Microscopic features of *Aureoboletus duplicatoporus* (FHMU1940). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. Scale bars = 10 µm. Drawings by X. Zhang.

**Holotype:** GDGM4677 (China, Guangdong Province).

**Materials examined:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 550 m, 5 Jun. 2017, N.K. Zeng, Zeng3077 (FHMU2038); same location, 13 Aug. 2020, N.K. Zeng, Zeng4709 (FHMU4964).

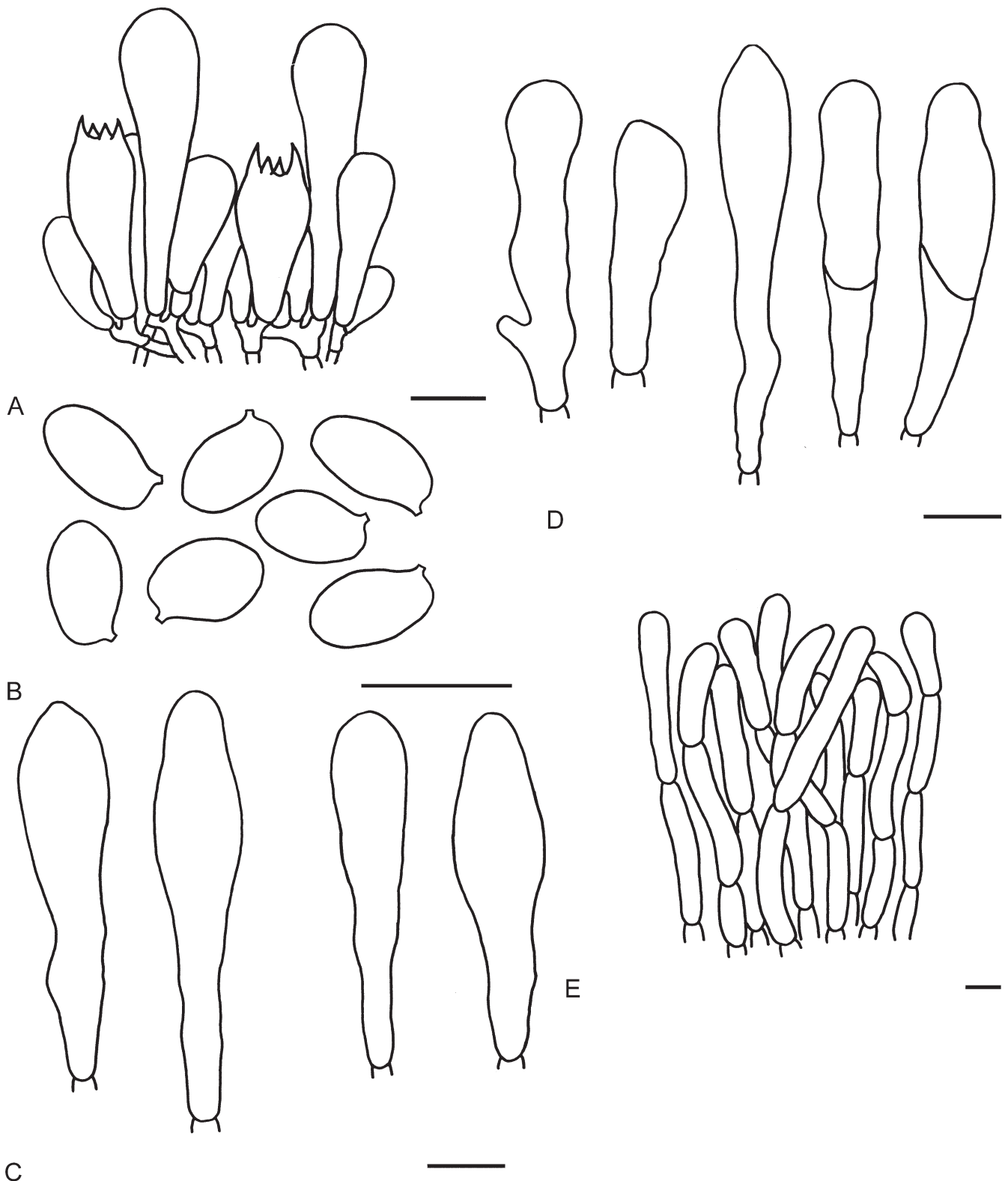
**Notes:** *Aureoboletus miniatoaurantiacus* was described from Guangdong Province, southern China by Bi *et al.* (1982). It was first classified in the genus *Boletus*, but was later transferred to *Aureoboletus* by Zhang *et al.* (2019a). The species is characterised by a small to medium-sized basidioma, a dry, yellowish orange to orange pileus with a tomentose or pulverous surface, a yellowish hymenophore surface, and a trichodermal pileipellis composed of mostly uninflated hyphae (up to 13 µm). It is common in tropical and subtropical regions of China (Wu *et al.* 2016, Zhang *et al.* 2019a).

***Aureoboletus nephrosporus*** G. Wu & Zhu L. Yang, Fungal Diversity 81: 47. 2016. MycoBank MB 818386.

**Known distribution:** Southwestern China (Yunnan Province) (Wu *et al.* 2016).

**Holotype:** KUN-HKAS74929 (China, Yunnan Province).

**Notes:** *Aureoboletus nephrosporus* was originally described from Yunnan Province, southwestern China (Wu *et al.* 2016), and subsequently also reported from India (Chakraborty *et al.* 2017). Illustrations and a full description of the species have been provided by Wu *et al.* (2016).



**Fig. 12.** Microscopic features of *Aureoboletus miniatoaurantiacus* (FHMU4964). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. Scale bars = 10 µm. Drawings by X. Zhang.

***Aureoboletus ornatipes*** N.K. Zeng, Xu Zhang & Zhi Q. Liang, *sp. nov.* MycoBank MB 846904. Figs 7J–L, 13.

**Etymology:** *ornatipes* (Lat.), refers to the reticulated stipe.

**Diagnosis:** Differs from other species of *Aureoboletus* by a large basidioma, a reddish brown, dry pileal surface, a reticulated stipe, and a trichodermal pileipellis.

**Typus:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 750 m, 28 May 2017, N.K. Zeng, Zeng3020 (**holotype** FHMU1981).

**Description:** *Basidiomata* large-sized. *Pileus* up to 10 cm diam, convex to applanate; surface dry, reddish brown (8B3); context yellowish (6B2), unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores angular to subround,

yellow (6B2), unchanging in colour when injured; tubes about 3 cm in length, yellowish (5B3), unchanging in colour when injured. *Stipe* 9 × 2 cm, central, subcylindrical or subclavate; surface reticulate, reddish brown (8B3); context yellowish (6B2), unchanging in colour when injured. *Basal mycelium* white (1A1). *Odour* indistinct.

*Basidia* 23–29 × 8–10 µm, clavate, thin- to slightly thick-walled (up to 1 µm), 4-spored, yellowish in KOH; sterigmata 3–4 µm in length. *Basidiospores* [20/1/1] 10–12.5(–13) × 4–5 µm,  $Q = 2.2–2.6(–3)$ ,  $Q_m = 2.45 \pm 0.26$ , cylindrical, slightly thick-walled (up to 1 µm), smooth, olive brown to yellowish brown in KOH. *Cheilocystidia* 46–57 × 8.5–11 µm, subfusiform, thin- to slightly thick-walled (up to 1 µm), yellowish in KOH. *Pleurocystidia* 52–60 × 10–11 µm, fusoid-ventricose, yellowish in KOH, thin- to slightly thick-walled (up to 1 µm). *Hymenophoral trama* bilateral, composed of hyphae 5–10 µm wide, thin- to slightly thick-walled (up to 1 µm), yellowish in KOH. *Pileipellis* a trichoderm 300–500 µm thick, made up of hyphae 5–11 µm diam, yellowish to brownish yellow in KOH; terminal cells 30–95 × 6–9 µm, subclavate or subcylindrical, with obtuse apex. *Pileal trama* composed of hyphae 5–13 µm diam, thin- to slightly thick-walled (up to 1 µm), yellowish in KOH. *Stipitipellis* a trichoderm-like structure 150–250 µm thick, made up of hyphae 8–20 µm diam, thin-walled, brownish yellow in KOH; terminal cells 40–60 × 8–19 µm, broadly clavate, subcylindrical or subfusiform, with obtuse apex. *Stipe trama* composed of parallel hyphae 5–13 µm wide, slightly thick-walled (up to 1 µm), yellowish in KOH. *Clamp connections* absent in all tissues.

*Habitat*: Solitary on the ground in forests dominated by fagaceous trees.

*Known distribution*: Southern China (Hainan Province).

*Notes*: Morphologically, *A. ornatipes* is somewhat similar to North American *A. mirabilis*, *A. projectellus*, and *A. russellii*, which are also characterised by a reticulated stipe. However, *A. mirabilis* has a larger basidioma (pileus up to 15 cm diam) and larger basidiospores measuring 18–22 × 7–9 µm (Singer 1945b, Thiers 1966); *A. projectellus* has a larger basidioma (pileus up to 20 cm diam), larger basidiospores measuring 18–33 × 7.5–12 µm, and it is associated with pine trees (Bessette *et al.* 2016); *A. russellii* has a coarsely and deeply pocketed-reticulate stipe and longitudinally ridged basidiospores (Halling *et al.* 2015). Phylogenetically, *A. ornatipes* is closely related to *A. clavatus*. However, *A. clavatus*, originally described from Hainan Province of southern China, has a context changing yellowish olivaceous when injured, a stipe without reticula, broadly ellipsoid to ellipsoid basidiospores measuring 7–8 × 5.5–6 µm, and a pileipellis composed of a turf of clavate hyphae (Zeng *et al.* 2015).

***Aureoboletus quercus-spinosae*** Ming Zhang & T.H. Li, *Mycoscience* 58 (3): 193. 2017. MycoBank MB 817376.

*Known distribution*: Southwestern China (Tibet) (Zhang *et al.* 2017).

*Holotype*: GDGM43755 (China, Tibet Autonomous Region).

*Notes*: *Aureoboletus quercus-spinosae* was originally described from Tibet, southwestern China (Zhang *et al.* 2017); illustrations and a full description of the species have been provided by Zhang *et al.* (2017).

***Aureoboletus raphanaceus*** Ming Zhang & T.H. Li, *Myckeys* 61: 126. 2019. MycoBank MB 827106. Figs 8A, B, 14.

*Description*: *Basidiomata* small to medium-sized. *Pileus* 3–6 cm diam, subhemispherical when young, then convex to applanate; surface slightly viscid when wet, subtomentose, white, tinged with brownish; context white, unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores angular to subround, pale yellow (1A2), unchanging in colour when injured; tubes about 0.4 cm in length, pale yellow (1A2), unchanging in colour when injured. *Stipe* 2.5–8 × 0.8–1.1 cm, central, subcylindrical or subclavate; surface white, sometimes tinged with brownish (5B3); context white, unchanging in colour when injured. *Basal mycelium* white. *Odour* indistinct.

*Basidia* 35–41 × 9.5–11 µm, clavate, thin- to slightly thick-walled (up to 1 µm), 4-spored, hyaline or yellowish in KOH; sterigmata 3.5–5 µm in length. *Basidiospores* [60/3/3] (7–)7.5–9(–9.5) × 5–6(–6.5) µm,  $Q = (1.27–)1.33–1.7(–1.9)$ ,  $Q_m = 1.51 \pm 0.12$ , ellipsoid, slightly thick-walled (up to 1 µm), smooth, yellowish in KOH. *Cheilocystidia* abundant, 45–60 × 10–18 µm, clavate to subfusiform, thin- to slightly thick-walled (up to 1 µm), yellowish white or hyaline in KOH, surface covered with a layer (1–10 µm thick) pale yellow substance. *Pleurocystidia* 52–60 × 12–20 µm, fusiform or subfusiform, yellowish in KOH, thin- to slightly thick-walled (up to 1 µm), surface covered with a layer (2–10 µm thick) pale yellow substance. *Hymenophoral trama* bilateral, composed of hyphae 4–10 µm wide, thin- to slightly thick-walled (up to 1 µm), yellowish in KOH. *Pileipellis* a trichoderm 150–250 µm thick, made up of hyphae 5–10 µm diam, occasionally branched, pale yellow or hyaline in KOH; terminal cells 34–38 × 5–7 µm, subcylindrical, with obtuse apex. *Pileal trama* composed of hyphae 4–15 µm diam, slightly thick-walled (up to 1 µm), hyaline in KOH. *Stipitipellis* a trichoderm-like structure 350–500 µm thick, made up of hyphae 4–13 µm diam, thin-walled, yellowish white or hyaline in KOH; terminal cells 30–40 × 3.5–4 µm, broadly clavate, subcylindrical, or subfusiform, with obtuse apex. *Stipe trama* composed of parallel hyphae 2–8 µm wide, slightly thick-walled (up to 1 µm), hyaline in KOH. *Clamp connections* absent in all tissues.

*Habitat*: Solitary or scattered on ground dominated by fagaceous trees.

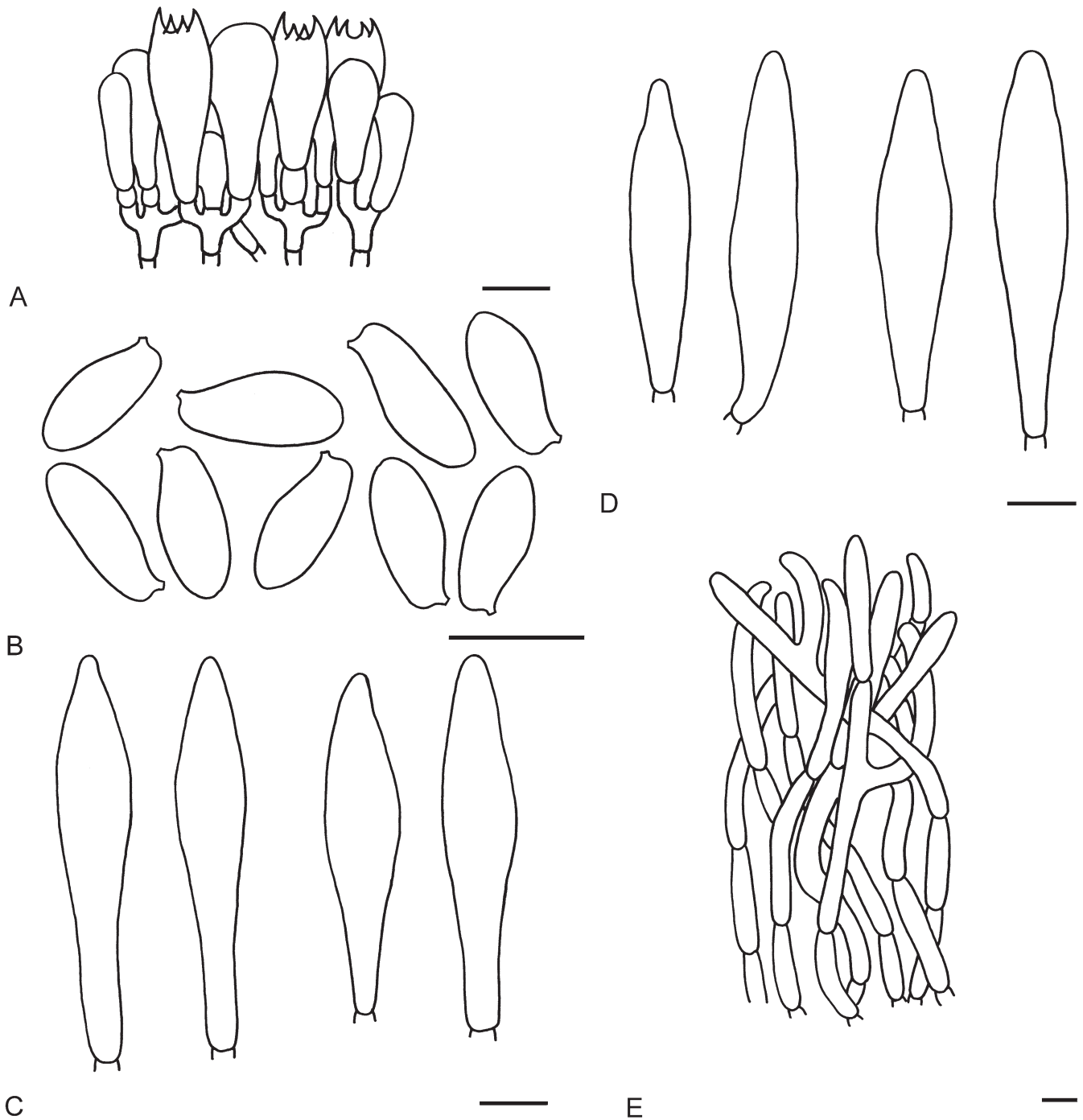
*Known distribution*: Central (Hunan Province), eastern (Jiangxi Province), southern (Hainan Province), and southwestern China (Yunnan Province) (Zhang *et al.* 2019a).

*Holotype*: GDGM45911 (China, Jiangxi Province).

*Materials examined*: **China**, Hainan Province, Limushan of Hainan Tropical Rainforest National Park, elev. 650 m, 26 Jun. 2015, N.K. Zeng, Zeng2007 (FHMU3597); Jianfengling of Hainan Tropical Rainforest National Park, elev. 850 m, 31 Jul. 2017, N.K. Zeng, Zeng3205 (FHMU2166); Yunnan Province, Tengchong County, Qushi Town, elev. 2 000 m, 31 Jun. 2015, S.D. Yang, Yang211 (FHMU5516).

*Notes*: *Aureoboletus raphanaceus* was originally described from Jiangxi Province, eastern China (Zhang *et al.* 2019a). In the present study, it was also found to be distributed in Hainan and Yunnan Provinces of China. The species is characterised by a small to medium-sized basidioma, a white pileus dry or slightly viscid when wet, a pale yellow hymenophore surface, wider basidiospores measuring 7.5–9 × 5–6 µm, and a trichodermal pileipellis composed of uninflated hyphae (up to 10 µm). According





**Fig. 13.** Microscopic features of *Aureoboletus ornatipes* (holotype FHMU1981). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. Scale bars = 10 µm. Drawings by X. Zhang.

to our new specimens, a thick layer of pale yellow substance on cystidia was observed, while septa in cystidia were absent.

***Aureoboletus rubellus*** Kuan Zhao & G. Wu, Phytotaxa 420: 75. 2019. MycoBank MB 832530.

**Known distribution:** Southern (Hainan Province) and eastern China (Jiangxi Province) (Fang *et al.* 2019).

**Holotype:** KUN-HKAS105265 (China, Jiangxi Province).

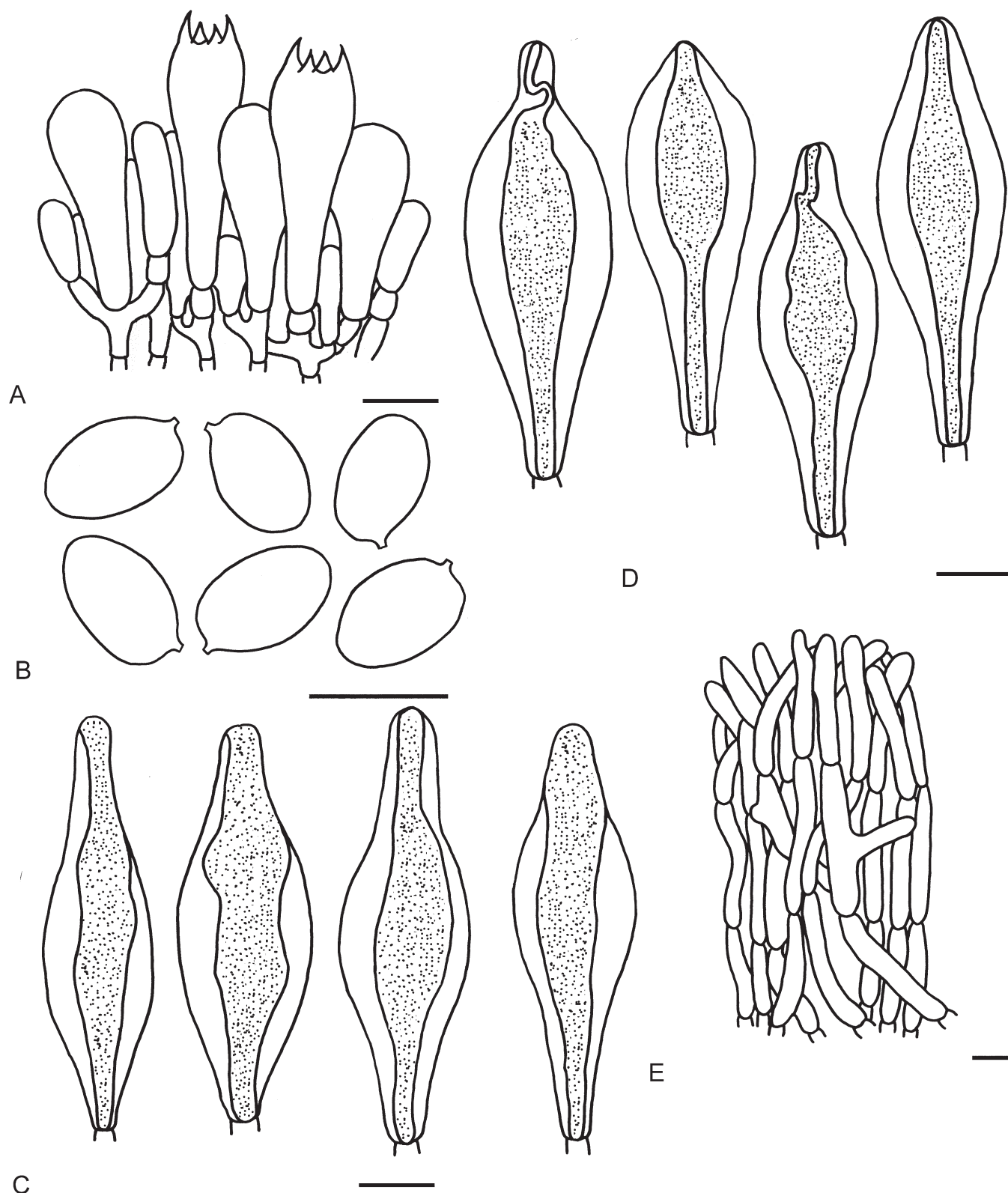
**Material examined:** **China**, Hainan Province, Jianfengling of Hainan Tropical Rainforest National Park, elev. 850 m, 10 Aug. 2020, N.K. Zeng, Zeng4592 (FHMU4877).

**Notes:** *Aureoboletus rubellus* was originally described from Jiangxi Province, eastern China (Fang *et al.* 2019); illustrations and a full description of the species have been provided by Fang *et al.* (2019). The Hainan specimen cited above extends the range of distribution and is the first report from tropical China.

***Aureoboletus rugosus*** N.K. Zeng *et al.*, Phytotaxa 567: 142. 2022. MycoBank MB 841625.

**Known distribution:** Southwestern China (Yunnan Province) (Zhang *et al.* 2022).

**Holotype:** FHMU6509 (China, Yunnan Province).



**Fig. 14.** Microscopic features of *Aureoboletus raphanaceus* (FHMU2166). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. Scale bars = 10  $\mu$ m. Drawings by X. Zhang.

*Notes:* *Aureoboletus rugosus* was originally described from Yunnan Province, southwestern China (Zhang *et al.* 2022). Illustrations and a full description of the species have been provided by Zhang *et al.* (2022).

***Aureoboletus shichianus*** (Teng & L. Ling) G. Wu & Zhu L. Yang, Fungal Diversity 81: 48. 2016. MycoBank MB 818387.

*Basionym:* *Boletus shichianus* Teng & L. Ling, Contr. Biol. Lab. Sci. Soc. China, Bot. Ser. 8: 99. 1932.

*Synonyms:* *Boletellus shichianus* (Teng & L. Ling) Teng, Chung-kuo Ti Chen-chun, [Fungi of China]: 759. 1964.

*Austroboletus shichianus* (Teng & L. Ling) E. Horak, Sydowia 33: 84. 1980.

**Known distribution:** Eastern (Zhejiang and Jiangxi Provinces) and southwestern China (Yunnan Province) (Wu *et al.* 2016).

**Epiletype:** HKAS77183 (China, Yunnan Province).

**Material examined:** China, Yunnan Province, Baoshan City, Baihualing, elev. 1 950 m, 8 Jul. 2018, Y.G. Fan, Fan2743 (FHMU7612).

**Notes:** *Aureoboletus shichianus* was originally described from Zhejiang Province, eastern China (Teng 1932). It was first classified in the genus *Boletus* and then transferred to *Boletellus* and *Austroboletus* successively (Teng 1932, 1963, Horak 1980). One recent study indicated it is a member of *Aureoboletus* (Wu *et al.* 2016). Illustrations and a full description of the species have been provided by Wu *et al.* (2016).

***Aureoboletus sinobadius*** Ming Zhang & T.H. Li, Mycokeys 61: 128. 2019. MycoBank MB 827101. Figs 8C, D, 15.

**Description:** *Basidiomata* small to medium-sized. *Pileus* 3.7–6.4 cm diam, subhemispherical when young, then convex to applanate; surface viscid, subtomentose, brownish violet when young, reddish brown to reddish violet when mature; context yellowish white, unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores angular to subround, pale yellow, unchanging in colour when injured; tubes 0.5–0.6 cm in length, pale yellow, unchanging in colour when injured. *Stipe* 8–10.5 × 1.3–1.5 cm, central, subcylindrical or subclavate; surface viscid when wet, pale brownish red when young, then pastel reddish violet, with distinct longitudinal streaks; context white to yellowish white, unchanging in colour when injured. *Basal mycelium* white. *Odour* indistinct.

*Basidia* 22–25 × 10–11.5 µm, clavate, thin- to slightly thick-walled (up to 1 µm), 4-spored, hyaline or yellowish in KOH; sterigmata 3–4 µm in length. *Basidiospores* [60/3/3] (8.5–) 9.5–12 × (4–) 4.5–5 µm,  $Q = (1.7–)1.9–2.75(–3)$ ,  $Q_m = 2.34 \pm 0.28$ , cylindrical, slightly thick-walled (up to 1 µm), smooth, yellowish brown in KOH. *Cheilocystidia* 32–44 × 9–15 µm, clavate to subfusiform, thin- to slightly thick-walled (up to 1 µm), yellowish white or hyaline in KOH. *Pleurocystidia* abundant, 42–54.5 × 11.5–17 µm, fusiform or subfusiform, yellowish in KOH, thin- to slightly thick-walled (up to 1 µm). *Hymenophoral trama* bilateral, composed of hyphae 4–10 µm wide, thin- to slightly thick-walled (up to 1 µm), yellowish in KOH. *Pileipellis* a trichoderm 300–500 µm thick, made up of hyphae 3–10 µm diam, occasionally branched, yellowish white or hyaline in KOH; terminal cells 25–43 × 5–9 µm, cystidioid, subclavate or subcylindrical, with obtuse (sometimes acute) apex. *Pileal trama* composed of hyphae 3–11 µm diam, slightly thick-walled (up to 1 µm), hyaline in KOH. *Stipitipellis* a trichoderm-like structure 300–500 µm thick, made up of hyphae 3–10 µm diam, thin-walled, yellowish white or hyaline in KOH; terminal cells 15–50 × 10–16 µm, broadly clavate, subcylindrical, or subfusiform, with obtuse apex. *Stipe trama* made up of parallel hyphae 4–6 µm wide, thin- to slightly thick-walled (up to 0.5 µm), hyaline in KOH. *Clamp connections* absent in all tissues.

**Habitat:** Solitary on the ground in forests dominated by fagaceous trees.

**Known distribution:** Central (Hunan Province) and southern China (Guangdong and Hainan Provinces) (Zhang *et al.* 2019a).

**Holotype:** GDGM71932 (China, Guangdong Province).

**Material examined:** China, Hainan Province, Jianfengling of Hainan Tropical Rainforest National Park, elev. 820 m, 28 Jun. 2018, N.K. Zeng, Zeng3494 (FHMU3117).

**Notes:** *Aureoboletus sinobadius* was originally described from Guangdong Province, southern China (Zhang *et al.* 2019a). In the present study, it was also found to be distributed in Hainan Province, tropical China. The species is characterised by a small to medium-sized basidioma, a viscid, brownish violet, reddish brown to reddish violet pileus, a pale yellow hymenophore surface, and a trichodermal pileipellis composed of uninflated hyphae (up to 10 µm). According to our new specimen, one of the diagnostic features, viz. the two shapes of basidiospores defined by Zhang *et al.* (2019a), was not observed.

***Aureoboletus solus*** Ming Zhang & T.H. Li, Mycokeys 61: 130. 2019. MycoBank MB 827105. Figs 8E, F, 16.

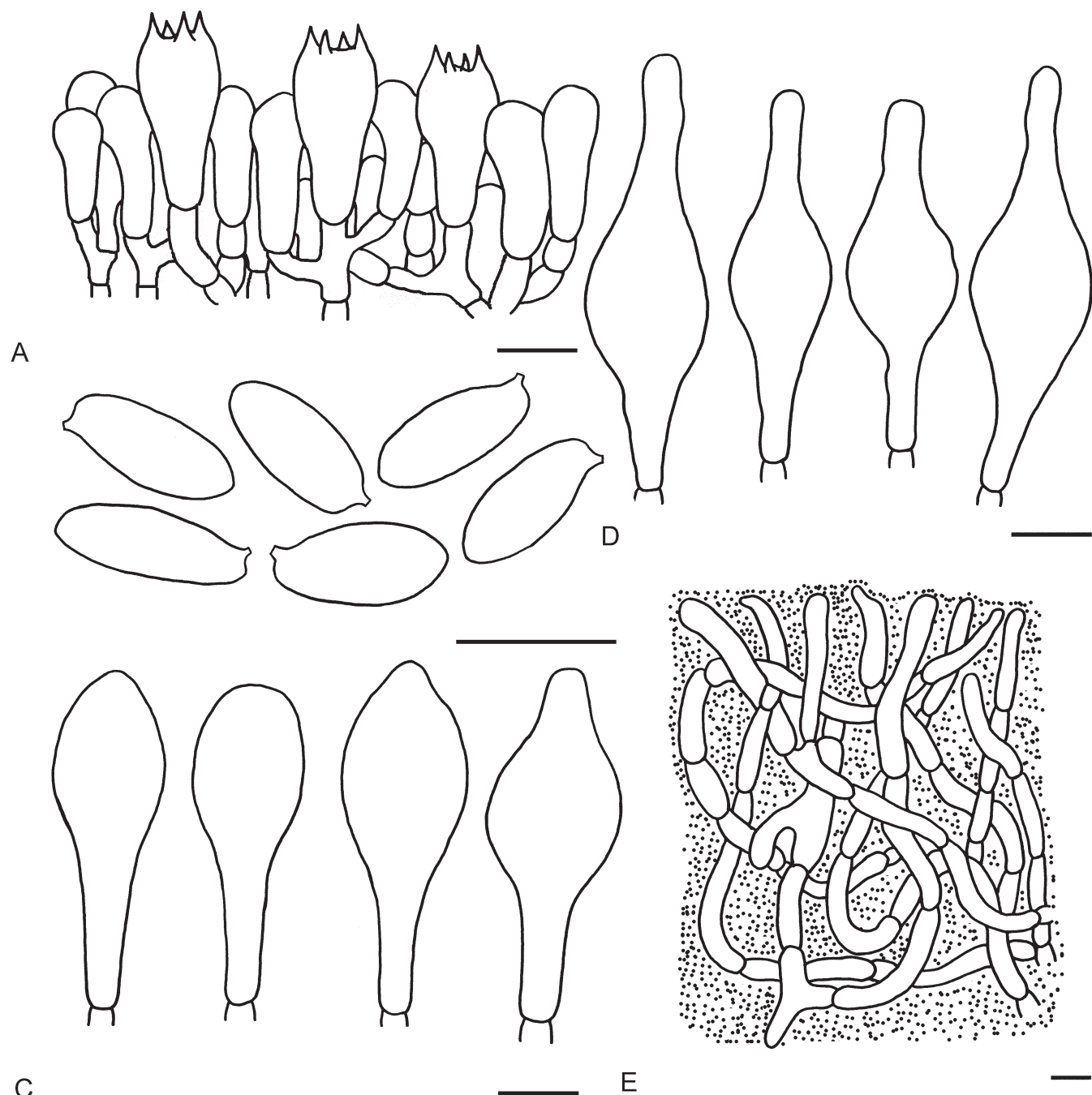
**Description:** *Basidiomata* very small-sized. *Pileus* 1.2–2.5 cm diam, subhemispherical when young, then convex to applanate; slightly viscid when wet, subtomentose, wrinkled, brownish yellow to brownish; context white, unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores angular to subround, yellow, unchanging in colour when injured; tubes about 0.2 cm in length, pale yellow, unchanging in colour when injured. *Stipe* 30 × 2 cm, central, subcylindrical or subclavate; surface pale brownish red, slightly viscid when wet; context white, unchanging in colour when injured. *Basal mycelium* white. *Odour* indistinct.

*Basidia* 32–40 × 10.5–13 µm, clavate, thin- to slightly thick-walled (up to 1 µm), 4-spored, hyaline or yellowish in KOH; sterigmata 3.5–5 µm in length. *Basidiospores* [60/3/2] (9–) 10–11.5(–12.5) × 4.5–5(–5.5) µm,  $Q = (1.8–)1.81–2.3(–2.4)$ ,  $Q_m = 2.1 \pm 0.15$ , elongate, slightly thick-walled (up to 1 µm), smooth, brownish yellow in KOH. *Cheilocystidia* 42–56 × 10–15 µm, fusoid-ventricose to clavate, thin- to thick-walled (up to 1.5 µm), yellowish white or hyaline in KOH. *Pleurocystidia* 50–60 × 10–15 µm, fusoid-ventricose, yellowish in KOH, thin- to slightly thick-walled (up to 1 µm). *Hymenophoral trama* bilateral, composed of hyphae 5–10 µm wide, thin- to slightly thick-walled (up to 1 µm), yellowish in KOH. *Pileipellis* a trichoderm 250–350 µm thick, composed of filamentous (sometimes slightly inflated) hyphae 5–13 µm diam, occasionally branched, yellowish white or hyaline in KOH; terminal cells 5–12 × 10–70 µm, subclavate or subcylindrical, with obtuse apex. *Pileal trama* composed of hyphae 2–7 µm diam, thin- to slightly thick-walled (up to 1 µm), hyaline in KOH. *Stipitipellis* a trichoderm-like structure 150–250 µm thick, made up of hyphae 3–27 µm diam, thin-walled, hyaline in KOH; terminal cells 15–27 × 5–6 µm, broadly clavate, subcylindrical, or subfusiform, with obtuse apex. *Stipe trama* composed of parallel hyphae 5–10 µm wide, thin- to slightly thick-walled (up to 1 µm), hyaline in KOH. *Clamp connections* absent in all tissues.

**Habitat:** Solitary on the ground in forests dominated by fagaceous trees.

**Known distribution:** Central (Hunan Province) and southern China (Guangdong and Hainan Provinces) (Zhang *et al.* 2019a).





**Fig. 15.** Microscopic features of *Aureoboletus sinobadius* (FHMU3117). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. Scale bars = 10  $\mu$ m. Drawings by X. Zhang.

*Holotype:* GDGM44759 (China, Guangdong Province).

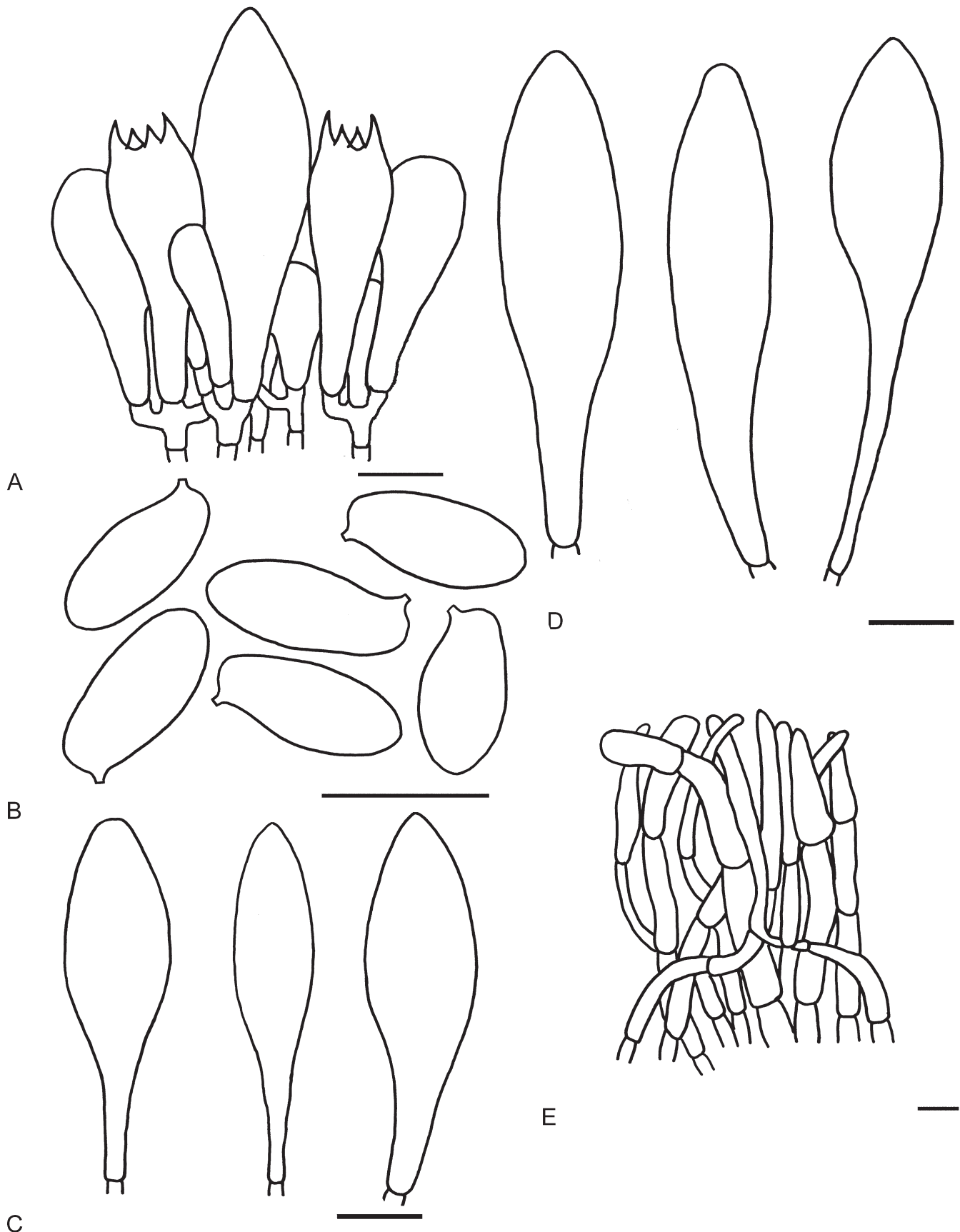
*Materials examined:* **China**, Hainan Province, Jianfengling of Hainan Tropical Rainforest National Park, elev. 850 m, 5 Jul. 2012, N.K. Zeng, Zeng1064 (FHMU715); Hunan Province, Mangshan National Nature Reserve, elev. 1 200 m, 29 Jul. 2019, N.K. Zeng, Zeng4146 (FHMU3750).

*Notes:* *Aureoboletus solus* was originally described from Guangdong Province, southern China (Zhang *et al.* 2019a). In the present study, it was also distributed in Hainan and Hunan Provinces of China. The species is characterised by a very small-sized basidioma, a brownish yellow to brownish pileus slightly viscid when wet, a yellow hymenophore surface, and a trichodermal pileipellis composed of mostly uninflated hyphae (up to 13  $\mu$ m).

*Aureoboletus tenuis* T.H. Li & Ming Zhang, Mycotaxon 128: 196. 2014. MycoBank MB 804773. Figs G–I, 17.

*Synonym:* *Aureoboletus marroninus* T.H. Li & Ming Zhang, Mycoscience 56: 482. 2015.

*Description:* *Basidiomata* very small-sized. *Pileus* 1.4–3.5 cm diam, subhemispherical, convex to applanate; surface strongly viscid when young, then dry, distinctly wrinkled when young, then squamulose, brown, reddish brown to purplish brown, veil remnants usually present on the margin of the pileus when young; context white, unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores 0.2–0.5 mm diam, angular to subround, yellow, unchanging in colour when injured; tubes about 0.4 cm in length, pale yellow, unchanging in colour



**Fig. 16.** Microscopic features of *Aureoboletus solus* (FHMU715). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. Scale bars = 10 µm. Drawings by X. Zhang.

when injured. *Stipe* 3–3.5 × 0.2–0.4 cm, central, subcylindrical or subclavate; surface strongly viscid when young, then dry, pale brownish red; context white, unchanging in colour when injured. *Basal mycelium* white. *Odour* indistinct.

*Basidia* 21–34 × 8–10 µm, clavate, thin- to slightly thick-walled (up to 1 µm), 4-spored, yellowish in KOH; sterigmata 3.5–5 µm in length. *Basidiospores* [40/2/2] 9.5–10.5(–11) × 4–5(–5.5) µm,  $Q = 1.8–2.22(–2.38)$ ,  $Q_m = 2.46 \pm 0.29$ , elongate, slightly thick-walled

(up to 1 µm), smooth, yellowish in KOH. *Cheilocystidia* 27–58 × 8–14 µm, subfusoid to clavate, thin- to thick-walled (up to 1.5 µm), yellowish white or hyaline in KOH. *Pleurocystidia* abundant, 50–65 × 10–15 µm, subfusoid, yellowish in KOH, thin- to slightly thick-walled (up to 1 µm). *Hymenophoral trama* bilateral, composed of hyphae 5–10 µm wide, thin- to slightly thick-walled (up to 1 µm), yellowish in KOH. *Pileipellis* an intricate trichoderm 400–700 µm thick, made up of hyphae 3–12 µm diam, yellowish white or hyaline in KOH; terminal cells 22–72 × 5–8 µm, subclavate or subcylindrical, with obtuse or subacute apex. *Pileal trama* composed of hyphae 6–14 µm diam, thin- to slightly thick-walled (up to 1 µm), hyaline in KOH. *Stipitipellis* a trichoderm-like structure 250–400 µm thick, made up of hyphae 3.5–5.5 µm diam, thin-walled, hyaline in KOH; terminal cells 33–63 × 4.5–5 µm, broadly clavate, subcylindrical, or subfusiform, with obtuse apex. *Stipe trama* composed of parallel hyphae 3–15 µm wide, thin- to thick-walled (up to 1.5 µm), hyaline in KOH. *Clamp connections* absent in all tissues.

**Habitat:** Solitary on the ground in forests dominated by fagaceous trees.

**Known distribution:** Southern (Guangxi and Guangdong Provinces) and southeastern China (Fujian Province) (Zhang *et al.* 2014, 2015b).

**Holotype:** GDGM42601 (China, Guangxi Province).

**Materials examined:** **China**, Fujian Province, Zhangping City, Xinqiao Town, Chengkou Village, elev. 350 m, 27 Jul. 2017, N.K. Zeng, Zeng1296, 1296-1 (FHMU850, 7496); Yongan City, Tianbaoyan National Nature Reserve, elev. 350 m, 17 Aug. 2017, N.K. Zeng, Zeng3264 (FHMU2225).

**Notes:** *Aureoboletus tenuis* was originally described from Guangxi Province, southern China (Zhang *et al.* 2014). In the present study, it was also found to be distributed in Fujian Province of China. This species is characterised by a very small-sized basidioma, a viscid, brown, reddish brown to purplish brown pileus distinctly wrinkled when young, then squamulose, a pileal margin usually with veil remnants, a yellow hymenophore surface, and an intricate ixotrichodermal pileipellis composed of mostly uninflated hyphae (up to 12 µm). One previous study showed that the phylogenetic distance between *A. tenuis* and *A. marroninus* is significantly smaller than the value for the interspecific variation of *Aureoboletus* species, indicating *A. tenuis* and *A. marroninus* are conspecific (Zhang *et al.* 2022). Current molecular phylogenetic analyses also show that the holotype of *A. tenuis* and the holotype of *A. marroninus* were in the same species-level lineage (Fig. 1). Interestingly, we also found that our two new collections (FHMU2225 and FHMU7496) fall into the lineage of *A. tenuis* (Fig. 1), despite their different macroscopic morphology (Fig. 8). These indicate the macromorphological features of *A. tenuis* are variable, which provides insights into the conspecific status of *A. tenuis* and *A. marroninus* despite somewhat morphological differences between the two taxa.

***Aureoboletus thibetanus*** (Pat.) Hongo & Nagas., Rep. Tottori Mycol. Inst. 18: 133. 1980. MycoBank MB 113146.

**Basionym:** *Boletus thibetanus* Pat., Bull. Soc. Mycol. France 11(4): 196. 1895.

**Synonyms:** *Suillus thibetanus* (Pat.) Kuntze: Revis. gen. pl. (Leipzig) 3(3): 536. 1898.

*Suillus thibetanus* (Pat.) F.L. Tai, Syll. Fung. Sinicorum. : 736. 1979.

*Pulveroboletus thibetanus* (Pat.) Singer, The Agaricales in modern

taxonomy. Edn 4: 774. 1986.

**Known distribution:** Southwestern China (Sichuan and Yunnan Provinces) (Wu *et al.* 2016, Gelardi 2017)

**Holotype:** Herb. Patouillard, FH 3711 (China, Sichuan Province).

**Material examined:** **China**, Yunnan Province, Kunming City, Kunming Botanical Garden, 23 Jul. 2011, elev. 1 950 m, N.K. Zeng, Zeng918 (FHMU561).

**Notes:** *Aureoboletus thibetanus* was originally described from Sichuan Province, southwestern China (Patouillard 1895). It was first classified in the genus *Boletus* (Patouillard 1895) and later transferred to *Suillus* and *Pulveroboletus* (Tai 1979, Singer 1986). Illustrations and a full description of the species have been provided by Yang *et al.* (2003) and Gelardi (2017).

***Aureoboletus velutipes*** Ming Zhang & T.H. Li, MycoKeys 61: 132. 2019. MycoBank MB 827108.

**Known distribution:** Southern (Guangdong and Guangxi Provinces) and eastern China (Jiangxi Province) (Zhang *et al.* 2019a)

**Holotype:** GDGM44713 (China, Guangdong Province).

**Notes:** *Aureoboletus velutipes* was originally described from Guangdong Province, southern China (Zhang *et al.* 2019a); illustrations and a full description of the species have been provided by Zhang *et al.* (2019a).

***Aureoboletus venustus*** Fang Li *et al.*, Mycol. Progr. 15: 1274. 2016. MycoBank MB 816327.

**Known distribution:** Southern China (Guangdong and Hainan Provinces) (Li *et al.* 2016, Wang *et al.* 2020).

**Holotype:** KUN-HKAS77700 (China, Guangdong Province).

**Materials examined:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 30 Jul. 2017, N.K. Zeng, Zeng3180-1 (FHMU7494); same location, 6 May 2018, N.K. Zeng, Zeng3345 (FHMU3146); same location, 3 Jul. 2020, S. Jiang, Jiang256, 259 (FHMU4776, 4784).

**Notes:** *Aureoboletus venustus* was originally described from Guangdong Province, southern China (Li *et al.* 2016), then it was also reported from Hainan Province, tropical China (Wang *et al.* 2020). Illustrations and a full description of the species have been provided by Li *et al.* (2016) and Wang *et al.* (2020).

***Aureoboletus viscidipes*** (Hongo) G. Wu & Zhu L. Yang, Fungal Diversity 81: 44. 2016. MycoBank MB 818389. Figs 8J, K, 18.

**Basionym:** *Suillus viscidipes* Hongo, J. Jap. Bot. 49: 301. 1974.

**Description:** *Basidiomata* very small-sized. *Pileus* about 1.9 cm diam, subhemispherical; surface nearly glabrous, sometimes distinctly wrinkled, strongly viscid, brownish; context white, unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores angular to subround, yellow, unchanging in colour when injured; tubes about 0.5 cm in length, pale yellow, unchanging in colour when injured. *Stipe* 4 × 0.3 cm, central, subcylindrical or subclavate; surface pale brown, strongly



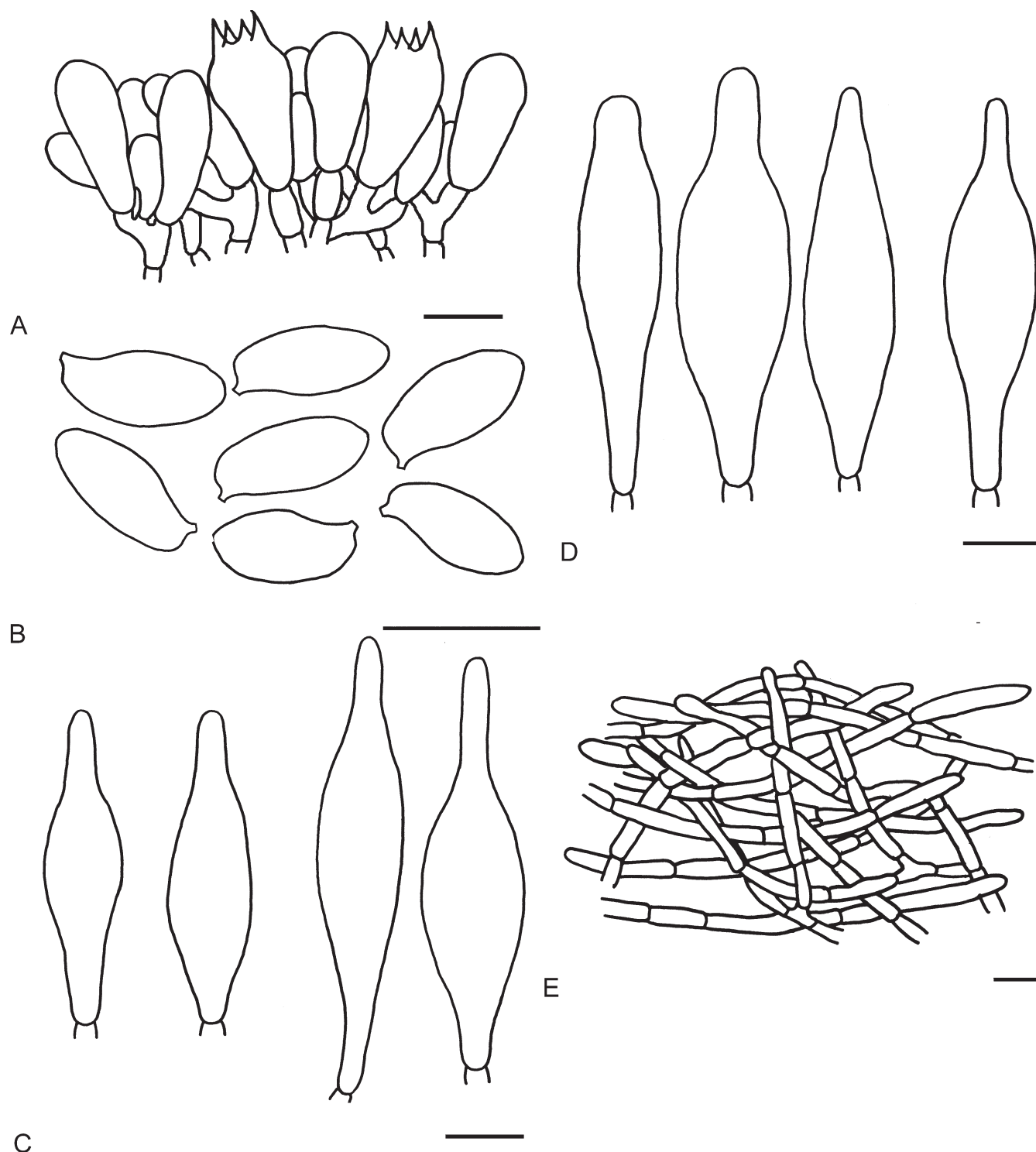


Fig. 17. Microscopic features of *Aureoboletus tenuis* (FHMU2225). A. Basidia. B. Basidiospores. C. Cheilocystidia. D. Pleurocystidia. E. Pileipellis. Scale bars = 10  $\mu$ m. Drawings by X. Zhang.

viscid; context white, unchanging in colour when injured. *Basal mycelium* white. *Odour* indistinct.

*Basidia* 27–35  $\times$  10.5–12  $\mu$ m, clavate, thin- to slightly thick-walled (up to 1  $\mu$ m), 4-spored, yellowish in KOH; sterigmata 3–4  $\mu$ m in length. *Basidiospores* [20/1/1] 12–15.5(–16)  $\times$  4–5.5(–6)  $\mu$ m,  $Q = 2.4$ –3.44(–3.56),  $Q_m = 2.93 \pm 0.29$ , cylindrical, slightly thick-walled (up to 1  $\mu$ m), smooth, yellowish brown in KOH. *Cheilocystidia* 28–40  $\times$  8–16  $\mu$ m, subfusoid or clavate, thin- to thick-walled (up to 1.5  $\mu$ m), yellowish white or hyaline in KOH. *Pleurocystidia* 38–50  $\times$  10–16  $\mu$ m, fusoid-ventricose, yellowish in KOH, thin- to slightly thick-walled (up to 1  $\mu$ m). *Hymenophoral trama* bilateral, composed

of hyphae 5–12  $\mu$ m wide, thin- to slightly thick-walled (up to 1  $\mu$ m), yellowish in KOH. *Pileipellis* an ixotrichoderm 150–300  $\mu$ m thick, made up of hyphae 3–12  $\mu$ m diam, yellowish white or hyaline in KOH; terminal cells 26–50  $\times$  3.5–9  $\mu$ m, subclavate or subcylindrical, with obtuse apex. *Pileal trama* composed of hyphae 5–19  $\mu$ m diam, thin- to slightly thick-walled (up to 1  $\mu$ m), hyaline in KOH. *Clamp connections* absent in all tissues.

*Habitat*: Solitary on the ground in forests dominated by *Pinus yunnanensis* and *Pin. armandii*.

**Known distribution:** Eastern (Jiangxi Province) and southwestern China (Yunnan Province) (Wu *et al.* 2016); Japan (Hongo 1974).

**Material examined:** **China**, Yunnan Province, Tengchong Prefecture-level City, near Dahe Reservoir, elev. 1 922 m, 29 Jul. 2015, S.D. Yang, Yang176 (FHMU5526).

**Notes:** *Aureoboletus viscidipes* was originally described from Japan (Hongo 1974), then also reported from Jiangxi Province, eastern China (Wu *et al.* 2016). In the present study, it was also found to be distributed in Yunnan Province, southwestern China. The species was first classified in the genus *Suillus* (Hongo 1974) and later transferred to *Aureoboletus* by Wu *et al.* (2016). It is characterised by a very small-sized basidioma, a viscid, wrinkled,

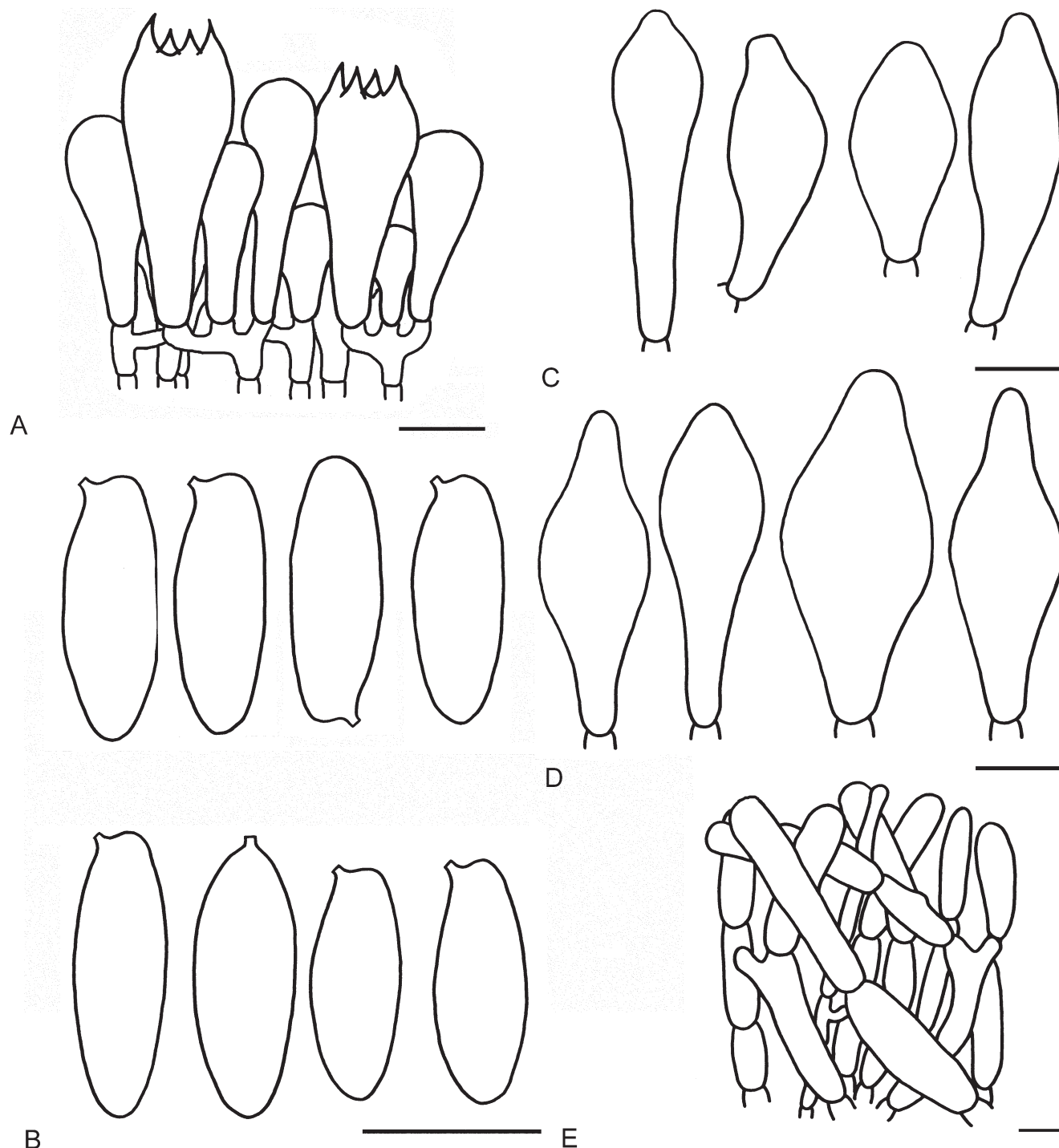
a yellow hymenophore surface, large basidiospores measuring  $12\text{--}15.5 \times 4\text{--}5.5 \mu\text{m}$ , and an ixotrichodermal pileipellis composed of mostly uninflated hyphae (up to  $12 \mu\text{m}$ ).

***Aureoboletus yunnanensis*** G. Wu & Zhu L. Yang, Fungal Diversity 81: 44. 2016. MycoBank MB 818391. Fig 8L.

**Known distribution:** Southwestern (Yunnan Province) and southeastern China (Fujian Province) (Wu *et al.* 2016).

**Holotype:** KUN-HKAS57581 (China, Yunnan Province).

**Material examined:** **China**, Fujian Province, Zhangping City, Tiantai National Forest Park, elev. 370 m, 28 Aug. 2009, N.K. Zeng, Zeng623 (FHMU392).



**Fig. 18.** Microscopic features of *Aureoboletus viscidipes* (FHMU5526). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. Scale bars =  $10 \mu\text{m}$ . Drawings by X. Zhang.

*Notes:* *Aureoboletus yunnanensis* was originally described from Yunnan Province, southwestern China (Wu *et al.* 2016); illustrations and a full description of the species have been provided by Wu *et al.* (2016). The Fujian specimen cited above extends the range of distribution.

*Aureoboletus zangii* X.F. Shi & P.G. Liu, Mycotaxon 123: 452. 2013. MycoBank MB 564683.

*Known distribution:* Northwestern (Shannxi Province), southwestern China (Guizhou and Yunnan Provinces) (Shi & Liu 2013, Wu *et al.* 2016).

*Holotype:* KUN-HKAS63217 (China, Shannxi Province).

*Notes:* *Aureoboletus zangii* was originally described from Shannxi Province, northwestern China (Shi & Liu 2013). Illustrations and a full description of the species have been provided by Shi & Liu (2013) and Wu *et al.* (2016).

## Key to accepted species of *Aureoboletus* in China

- 1a. Stipe surface with reticulation ..... *A. ornatipes*
- 1b. Stipe surface without reticulation ..... 2
- 2a. Pileal surface dry or slightly viscid when wet ..... 3
- 2b. Pileal surface viscid ..... 16
- 3a. Basidiomata medium to larger (pileus  $\geq 6$  cm diam) ..... 4
- 3b. Basidiomata smaller (pileus  $< 6$  cm diam) ..... 6
- 4a. Stipe surface white ..... *A. albipes*
- 4b. Stipe surface greyish yellow, blond, brownish red to reddish brown ..... 5
- 5a. Pileus 6–15 cm diam, brownish red to reddish brown, context yellowish white changing to yellowish olivaceous when injured, stipe surface brownish red to reddish brown, basidiospores  $7-8 \times 5.5-6 \mu\text{m}$  ..... *A. clavatus*
- 5b. Pileus 6–10 cm diam, greyish orange to brownish orange, stipe surface greyish yellow to blond, context unchanging in colour when injured, basidiospores  $9-11 \times 4-5.5 \mu\text{m}$  ..... *A. yunnanensis*
- 6a. Basidiospores with nodulose to verrucose ornamentations ..... *A. shichianus*
- 6b. Basidiospores smooth ..... 7
- 7a. Hymenophore surface bright yellow to vivid yellow, unchanging in colour when old ..... 8
- 7b. Hymenophore surface pale yellow, light yellow, greenish yellow to olive brown ..... 9
- 8a. Pileal surface greyish rose to brownish red, glabrous to slightly subtomentose, context pale yellow to light yellow unchanging in colour when injured, stipe surface dark orange to yellow ochre, with distinct longitudinal streaks and furfuraceous scales, basidiospores  $8-10.5 \times 5-6 \mu\text{m}$  ..... *A. nephrosporus*
- 8b. Pileal surface reddish brown to greyish ruby, smooth to minutely velvet-subtomentose, context white to yellowish white changing to greyish red to greyish rose when injured, stipe surface concolourous with pileus, smooth, basidiospores  $9-10.5 \times 4.5-5 \mu\text{m}$  ..... *A. griseorufescens*
- 9a. Pileal surface covered with a thin layer of white pruina when young ..... *A. rubellus*
- 9b. Pileal surface without white pruina ..... 10
- 10a. Pileal surface yellowish white to pinkish white ..... *A. raphanaceus*
- 10b. Pileal surface brownish orange, orangish brown, reddish brown, reddish violet, orangish yellow, reddish yellow, orange to reddish orange ..... 11
- 11a. Pileal surface yellowish orange to orange ..... *A. miniatoaurantiacus*
- 11b. Pileal surface brown, reddish brown to reddish violet ..... 12
- 12a. Pileal surface covered with conical squamules ..... *A. conicus*
- 12b. Pileal surface subtomentose, or covered with fibrillose to tomentose squamules ..... 13
- 13a. Pileal context changing greyish red, greyish rose or pastel red when injured ..... *A. velutipes*
- 13b. Pileal context unchanging in colour when injured ..... 14
- 14a. Basidiospores wider (up to  $6 \mu\text{m}$ ) ..... *A. guangdongensis*
- 14b. Basidiospores narrower (up to  $5 \mu\text{m}$ ) ..... 15



15a.	Basidiomata smaller (pileus 1.5–2.5 cm diam), pileipellis composed of hyphae 5–13 µm diam, basidiospores 10–11.5 × 4.5–5 µm	<i>A. solus</i>
15b.	Basidiomata larger (pileus 3.5–6 cm diam), pileipellis composed of hyphae 10–27 µm diam, basidiospores 7–9 × 3.5–5 µm	<i>A. catenarius</i>
16a.	Pileal margin with a gelatinised membranous veil	17
16b.	Pileal margin without any membranous veil	23
17a.	Stipe with annulus, basidiospores with longitudinal ridges	<i>A. longicollis</i>
17b.	Stipe without annulus, basidiospores smooth	18
18a.	Pileal surface distinctly reticulate or coarsely rugose	<i>A. thibetanus</i>
18b.	Pileal surface glabrous or slightly rugose	19
19a.	Pileus comparatively large (up to 3.5 cm)	20
19b.	Pileus comparatively small (up to 2.5 cm)	21
20a.	Basidiospores wider (up to 6 µm)	<i>A. rugosus</i>
20b.	Basidiospores narrower (up to 5 µm)	<i>A. tenuis</i>
21a.	Pileal surface reddish brown to ruby	<i>A. glutinosus</i>
21b.	Pileal surface brownish, brown to blackish brown	22
22a.	Basidiospores 12–15.5 × 4–5.5 µm	<i>A. viscidipes</i>
22b.	Basidiospores 8.5–12.5 × 4–5.5 µm	<i>A. microcarpus</i>
23a.	Basidiospores with $Qm > 3.0$	24
23b.	Basidiospores with $Qm < 3.0$	25
24a.	Pileal surface brownish red to deep red, greyish ruby to pink, basidiospore 15–16.5 × 4.5–5 µm, a distribution in subtropical China	<i>A. formosus</i>
24b.	Pileal surface pale yellow, light yellow, light orange, greyish yellow, greyish orange, brownish orange to brownish red, basidiospore 15–21 × 5–6.5 µm, a distribution in temperate China	<i>A. quercus-spinosae</i>
25a.	Basidiospores broadly ellipsoid, ellipsoid, elongate ( $Qm < 2.0$ )	<i>A. venustus</i>
25b.	Basidiospores subfusoid, cylindrical ( $2.0 \leq Qm < 3.0$ )	26
26a.	Pileus comparatively small (pileus up to 6 cm diam)	<i>A. zangii</i>
26b.	Pileus comparatively large (up to 11 cm diam)	27
27a.	Pileal surface tinged with violet	<i>A. sinobadius</i>
27b.	Pileal surface brown, brownish red, reddish brown to dark red	28
28a.	Hyphae in pileipellis wider (up to 17 µm diam)	<i>A. duplicatoporus</i>
28b.	Hyphae in pileipellis narrower (up to 9 µm diam)	<i>A. erythraeus</i>

**Boletellus** Murrill, Mycologia 1: 9. 1909.

*Boletellus* was originally erected to accommodate *Bol. ananas*, a species firstly described from USA with obvious longitudinal ridges, then Singer (1945a, 1986) further conceptualised the genus, which includes species with either smooth or variously ornamented basidiospores. However, Smith & Thiers (1971) disagreed with Singer's definition of the genus, advocating that the genus only includes species with basidiospores furnished with more or less longitudinal wings, ridges, or striation. Recent molecular phylogenetic analyses also indicated that the genus in the broad sense is polyphyletic, some species such as *Bol. longicollis*, *Bol. mirabilis*, *Bol. projectellus*, *Bol. shichianus* and *Bol. viscosus* are truly members of *Aureoboletus* (Halling *et al.* 2015, Zeng *et al.* 2015, Wu *et al.* 2016). Besides five new species described in the present study, 12 species were confirmed to be distributed in China (Wen 1985, Zang 1985,

Wang & Liu 2002, Zeng & Yang 2011, Wu *et al.* 2016, Lin *et al.* 2022, Xu *et al.* 2022, Zhang & Wu 2022).

***Boletellus* aff. *putuoensis*** N.K. Zeng *et al.*, Phytotaxa 554: 156. 2022. Figs 19A, B, 23A, 25A, 27.

**Description:** *Basidiomata* medium-sized. *Pileus* about 6 cm diam, cup-shaped, margin uplifted; surface dry, densely covered with brown to dark brown, appressed scales; context about 1 cm thick in the centre of the pileus, white, turning blue quickly when injured. *Hymenophore* poroid, depressed around apex of stipe; pores angular, about 0.5 mm diam, pale yellow, turning blue quickly when injured; tubes about 0.5 cm in length, pale yellow, turning blue quickly when injured. *Stipe* 5.5 × 0.8 cm long, central, subcylindrical, slightly enlarged at base, solid; surface dry, densely covered with appressed, reddish brown scales; context dull red,





Fig. 19. Basidiomata of *Boletellus* species. A, B. *Bol. aff. putuoensis* (FHMU2168). C–F. *Bol. areolatus* (C. FHMU2073; D–F. KUN-HKAS92436). G, H. *Bol. brunoflavus* (FHMU3249). I–L. *Bol. emodensis* (I. FHMU3252; J. FHMU2154; K. FHMU2034; L. FHMU434). A–C, G–L photos by N.K. Zeng; D–F photos by K. Zhao.

but white near the apex, turning blue quickly when injured; annulus absent; basal mycelium white. *Odour* indistinct.

*Basidia* 28–45 × 10–14.5 µm, clavate, thin- to slightly thick-walled (up to 1 µm), 4-spored, colourless to yellowish brown in KOH; sterigmata 4–6 µm in length. *Basidiospores* [20/1/1] 9.5–11.5 × 5.5–6.5 µm, Q = 1.58–1.91, Qm = 1.71 ± 0.07, yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with 5–8 longitudinal or

oblique ridges visible in lateral view; ridges continuous or forked, shallowly and moderately spaced, projecting 0.5–1 µm, united at the apex, without cross-striations on the ridges observed under the light microscope. *Hymenophoral trama* boletoid, composed of hyphae 4–16 µm wide, colourless in KOH. *Cheilocystidia* 32–52 × 7–15 µm, abundant, subfusiform or fusiform, thin- to slightly thick-walled (up to 1 µm), colourless in KOH, no encrustations. *Pleurocystidia* 40–73 ×





**Fig. 20.** Basidiomata of *Boletellus* species. **A–E.** *Bol. erythrolepis* (**A, C.** holotype FHMU3255; **B, D, E.** FHMU913). **F, G.** *Bol. fanjingensis* (holotype HMAS45914). **H, I.** *Bol. fujianensis* (holotype HMAS45913). **A, C** photos by S. Jiang; **B, D–I** photos by N.K. Zeng.

7–16  $\mu\text{m}$ , abundant, subfusiform or fusiform, thin- to slightly thick-walled (up to 1  $\mu\text{m}$ ), colourless in KOH, no encrustations. *Pileipellis* a trichoderm 156–200  $\mu\text{m}$  thick, composed of interlaced, filamentous hyphae, 7–12  $\mu\text{m}$  diam, thin-walled, yellowish to yellowish brown in KOH; terminal cells 20–85  $\times$  8–15  $\mu\text{m}$ , clavate to subcylindrical, with obtuse or acute apex. *Pileus trama* composed of interwoven hyphae 9–15  $\mu\text{m}$  diam, subcylindrical, thin-walled, colourless in KOH. *Stipitipellis* a trichoderm-like structure about 150  $\mu\text{m}$  thick, composed of slightly interlaced, filamentous hyphae, thin-walled, 5–7  $\mu\text{m}$  diam, colourless to yellow in KOH; terminal cells 20–60  $\times$  6–15  $\mu\text{m}$ , clavate to subcylindrical. *Stipe trama* composed of longitudinally arranged, parallel hyphae 6–11  $\mu\text{m}$  wide, cylindrical, thin-walled, colourless in KOH. *Clamp connections* absent in all tissues.

**Habitat:** Solitary on the ground in forests dominated by fagaceous trees.

**Known distribution:** Southern China (Hainan Province).

**Material examined:** **China**, Hainan Province, Jianfengling of Hainan Tropical Rainforest National Park, elev. 900 m, 31 Jul. 2017, N.K. Zeng, Zeng3207 (FHMU2168).

**Notes:** Based on both morphological and molecular analyses, the new collection shows a close resemblance to *Bol. putuoensis*, with low genetic variation (Fig. 2) and overlapping morphological features. However, further research is needed to establish the exact taxonomic relationship between the two, requiring additional samples and DNA sequences. Therefore, for the time being, the new specimen found in tropical China is tentatively identified as *Bol. aff. putuoensis*.

***Boletellus areolatus*** Hirot. Sato, PLoS ONE 10: e0128184. 2015. MycoBank MB 810178. Figs 19C–F, 23B, 25B, 28.

**Description:** Basidiomata medium-sized. *Pileus* 5.5–7 cm diam, subhemispherical to convex, then applanate, margin at first extending into a false veil and covering the pores, then splitting radially, appendiculate with false veil remnants; surface dry, red, usually fading to pale fawn in age, tomentose when young, then cracking into large, more or less erect scales; context 0.8–1 cm thick in the centre of pileus, white, turning blue strongly and quickly when injured. *Hymenophore* poroid, depressed around apex of stipe; pores 0.5–1 mm diam, angular, yellow, turning blue strongly and quickly when injured; tubes about 1 cm in length, yellowish, turning blue quickly when injured. *Stipe* 7–9  $\times$  1–1.5 cm, central,





Fig. 21. Basidiomata of *Boletellus* species. A–D. *Bol. indistinctus* (A. FHMU3613; B. FHMU2028; C, D. FHMU1088). E–G. *Bol. putuoensis* (E. FHMU3260; F, G. FHMU3261). H, I. *Bol. rubidus* (holotype KUN-HKAS83069). J, K. *Bol. sinochrysenderoides* (J. FHMU3265; K. holotype FHMU3264). A–G photos by N.K. Zeng; H, I photos by Y.J. Hao; J, K photos by K. Zhao.

subcylindrical, solid; surface dry, fibrous, concolourous with pileus; context white, turning blue strongly and quickly when injured; annulus absent; basal mycelium white. *Odour* indistinct.

*Basidia* 30–50 × 10–15 µm, clavate, thin-walled, 4-spored, light yellow to yellowish brown in KOH; sterigmata 4–6 µm in length. *Basidiospores* [140/7/7] 15–21 × 7–10 µm,  $Q = 1.85\text{--}2.47$ ,  $Q_m = 2.11 \pm 0.17$ , yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with longitudinal or oblique ridges, 5–8 ridges visible in lateral view; ridges continuous or forked, united at the apex, projecting 1–2

µm, with cross-striations on the ridges observed under the light microscope. *Hymenophoral trama* boletoid, composed of hyphae 5–13 µm wide, colourless to yellowish in KOH. *Cheilocystidia* 28–55 × 8–16 µm, abundant, subfusiform or fusiform, thin-walled, colourless to yellowish brown in KOH, no encrustations. *Pleurocystidia* 38–65 × 11–17 µm, abundant, subfusiform or fusiform, thin- to slightly thick-walled (up to 1 µm), colourless in KOH, no encrustations. *Pileipellis* a trichoderm about 220 µm thick, composed of slightly interlaced, filamentous hyphae, 6–10 µm diam, thin-walled, light yellow in



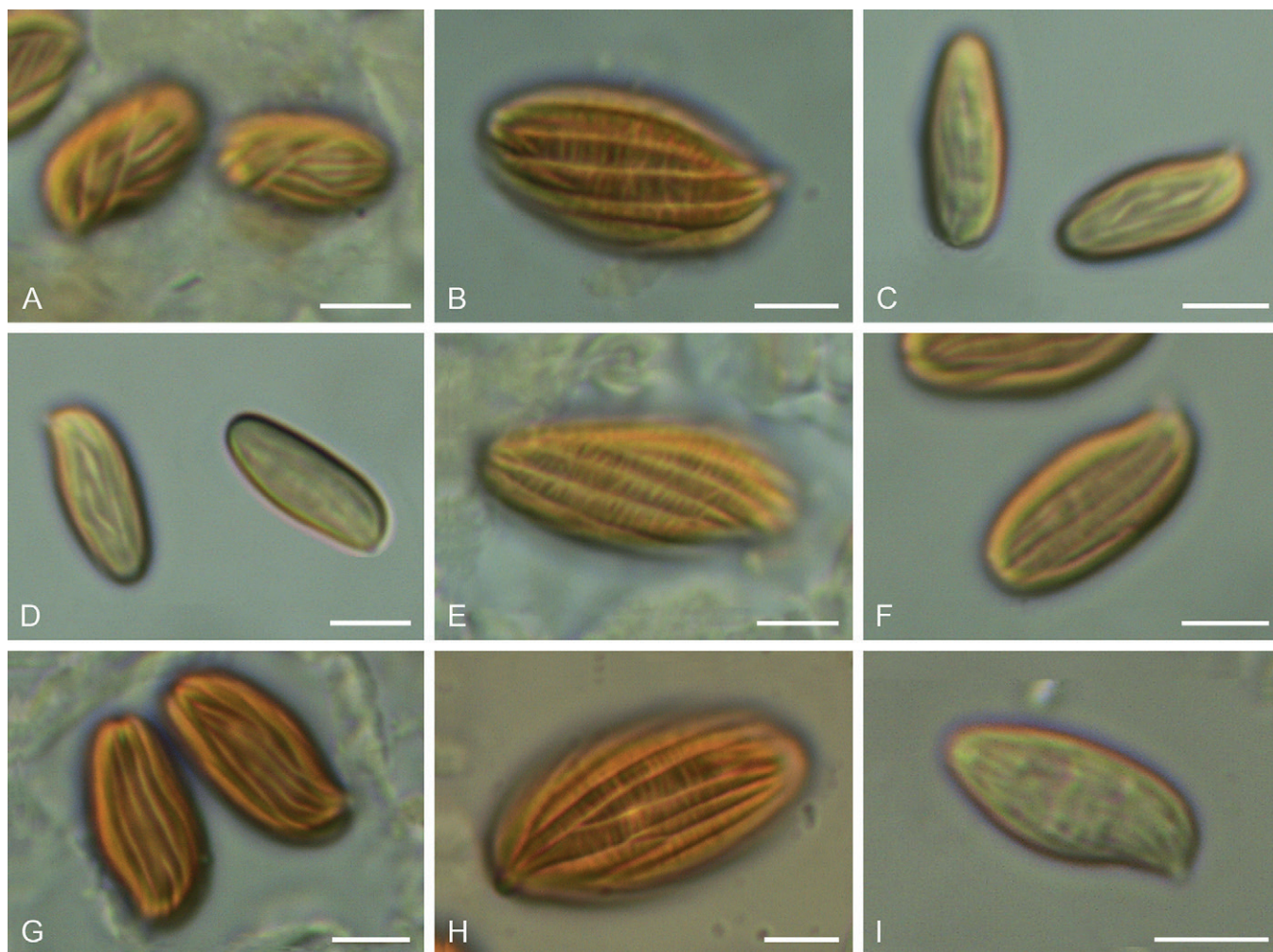


Fig. 22. Basidiomata of *Boletellus* species. A–C. *Bol. squamosus* (A, B. holotype KUN-HKAS4112; C. FHMU3266). D, E. *Bol. subglobosus* (holotype FHMU3256). F, G. *Bol. violaceus* (holotype KUN-HKAS10249). H, I. *Bol. yunnanensis* (holotype KUN-HKAS2871). J, K. *Bol. zenghuoxingii* (FHMU1979). A–C, F–K photos by N.K. Zeng; D, E photos by S. Jiang.

KOH; terminal cells  $22\text{--}80 \times 5.5\text{--}11\ \mu\text{m}$ , clavate to subcylindrical, with obtuse apex. *Pileus trama* composed of interlaced hyphae  $7\text{--}11\ \mu\text{m}$  diam, subcylindrical, thin-walled, colourless in KOH. *Stipitipellis* a trichoderm-like structure about  $140\ \mu\text{m}$  thick, composed of erect, slightly interlaced, filamentous hyphae, thin-walled,  $5.5\text{--}8\ \mu\text{m}$  diam,

colourless to light yellow in KOH; terminal cells  $20\text{--}67 \times 5\text{--}8\ \mu\text{m}$ , clavate to subcylindrical. *Stipe trama* composed of longitudinally arranged, parallel hyphae  $5\text{--}13\ \mu\text{m}$  wide, cylindrical, thin- to slightly thick-walled (up to  $0.5\ \mu\text{m}$ ), yellowish in KOH. *Clamp connections* absent in all tissues.





**Fig. 23.** Basidiospores of *Boletellus* species from herbarium materials under light microscope. **A.** *Bol. aff. putuoensis* (FHMU2168). **B.** *Bol. areolatus* (FHMU2046). **C, D.** *Bol. brunoflavus* (FHMU3249). **E.** *Bol. emodensis* (FHMU2034). **F.** *Bol. erythrolepis* (holotype FHMU3255). **G.** *Bol. fanjingensis* (holotype HMAS45914). **H.** *Bol. fujianensis* (holotype HMAS45913). **I.** *Bol. indistinctus* (FHMU936). Scale bars = 5  $\mu$ m. Photos by R. Xue.

**Habitat:** Solitary on the ground in forests dominated by fagaceous trees.

**Known distribution:** Southern (Hainan Province), central (Hunan Province), and southwestern China (Yunnan Province); Japan (Sato & Hattori 2015).

**Holotype:** TNS F-61568 (Japan, Kyushu).

**Materials examined:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 600 m, 5 Jun. 2017, N.K. Zeng, Zeng3085 (FHMU2046); Limushan of Hainan Tropical Rainforest National Park, elev. 650 m, 26 Jul. 2017, N.K. Zeng, Zeng3112 (FHMU2073); Yunnan Province, Jinghong City, Dadugang Town, 29 Jun. 2014, K. Zhao, Zhao451 (KUN-HKAS89114); Gonglang Town, near Yangdian River, 1 Jul. 2015, K. Zhao, Zhao806 (KUN-HKAS92436); Wenshan City, Maguan County, Qiaotou Town, Dawanzi Village, elev. 1 206 m, 27 Jul. 2016, G. Wu, Wu1642 (KUN-HKAS99761); Wenshan City, Maguan County, Qiaotou Town, Xiaxinzhai Village, elev. 1 206 m, 27 Jul. 2016, G. Wu, Wu1648 (KUN-HKAS99767); Wenshan City, Malipo County, Mali Town, Nanyatian Village, elev. 1 175 m, 30 Jul. 2016, G. Wu, Wu1674 (KUN-HKAS99793); Hunan Province, Yizhang County, Mangshan National Nature Reserve, 30 Jul. 2019, N.K. Zeng, Zeng4186 (FHMU3305).

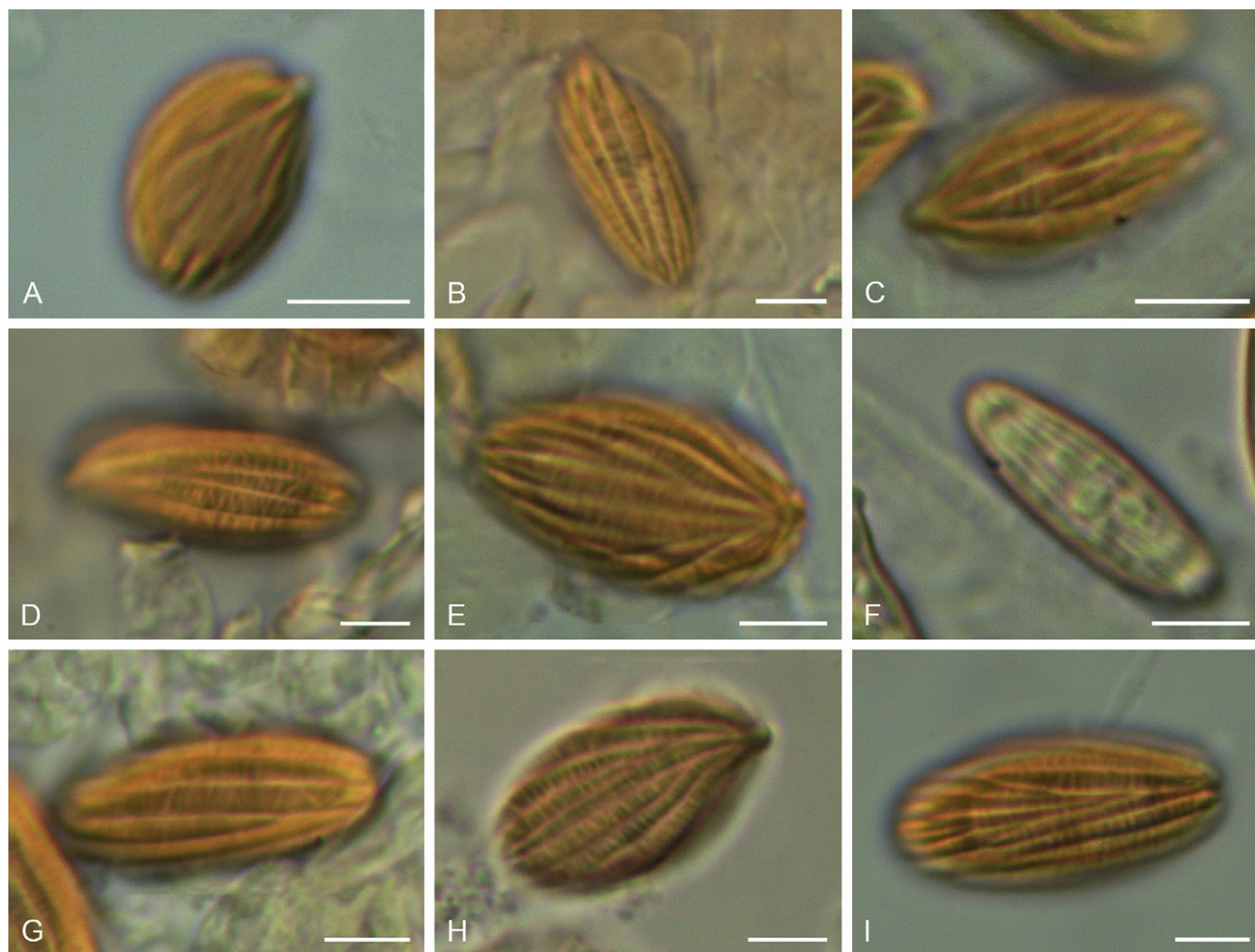
**Notes:** *Boletellus areolatus* was first described from Japan (Sato & Hattori 2015). In the present study, it was also found to be distributed in Hainan, Yunnan, and Hunan Provinces of China. The

species was redescribed according to Chinese specimens, which is characterised by a red pileus covered with large, more or less erect scales, a white context, hymenophore and context turning blue when injured, large, distinctly striate basidiospores with cross-striations on ridges, and a pileipellis composed of filamentous hyphae. Sato & Hattori (2015) pointed out that the pallid or pale cream colour at the upper half of the stipe is an important diagnostic feature; however, according to our examinations based on the new collections from China, the upper half of the stipe is yellow when young, then red when mature, and fading to pallid or pale cream when old. Moreover, cross-striations on the ridges of basidiospores were observed in the present study, whereas the feature was neglected in the protologue (Sato & Hattori 2015).

***Boletellus brunoflavus*** Z.J. Lin *et al.*, Phytotaxa 567: 251. 2022. MycoBank MB 843835. Figs 19G, H, 23C, D, 25C, D, 29.

**Description:** *Basidiomata* small-sized. *Pileus* 2.5–3.5 cm diam, subhemispherical to convex margin decurved; surface dry, tomentose, brown; context about 0.6 cm thick in the centre of the pileus, yellowish, turning blue quickly when injured. *Hymenophore* poroid, depressed around apex of stipe; pores angular, 0.5 mm diam, yellow, turning blue quickly, then brown slowly when injured; tubes about 0.4 cm in length, pale yellow, turning blue quickly when injured. *Stipe* 5–6 × 0.5–0.8 cm, central, subcylindrical, solid;





**Fig. 24.** Basidiospores of *Boletellus* species from herbarium materials under light microscope. **A.** *Bol. putuoensis* (FHMU3261). **B.** *Bol. rubidus* (holotype KUN-HKAS83069). **C.** *Bol. sinochrysenteroides* (holotype FHMU3264). **D, E.** *Bol. squamosus* (**D.** holotype KUN-HKAS4112; **E.** FHMU3266). **F.** *Bol. subglobosus* (holotype FHMU3256). **G.** *Bol. violaceus* (holotype KUN-HKAS10249). **H.** *Bol. yunnanensis* (holotype KUN-HKAS2871). **I.** *Bol. zenghuoxingii* (FHMU1979). Scale bars = 5  $\mu$ m. Photos by R. Xue.

surface dry, tomentose, reddish brown to brown, but yellow near the apex; context yellowish brown to reddish brown, but yellowish white near the apex, turning blue when injured; annulus absent; basal mycelium white. *Odour* indistinct.

*Basidia* 20–34.5  $\times$  7–11  $\mu$ m, clavate, thin- to slightly thick-walled (up to 0.5  $\mu$ m), 4-spored, colourless to yellowish in KOH; sterigmata 3–4  $\mu$ m in length. *Basidiospores* [100/5/2] (9–)10–12.5(–13)  $\times$  4–5  $\mu$ m,  $Q = (1.9\text{--})2.1\text{--}2.78(\text{--}3)$ ,  $Q_m = 2.45 \pm 0.20$ , yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with shallowly longitudinal or oblique ridges, 5–8 ridges visible in lateral view, ridges continuous or forked, projecting 0.5  $\mu$ m, united at the apex, without cross-striations on the ridges observed under the light microscope. *Hymenophoral trama* boletoid, composed of hyphae 4–11  $\mu$ m wide, colourless to yellowish in KOH. *Cheilocystidia* 30–41  $\times$  8–10  $\mu$ m, subfusiform or fusiform, thin-walled, colourless to yellowish brown in KOH, no encrustations. *Pleurocystidia* 35–56  $\times$  9–12  $\mu$ m, subfusiform or fusiform, thin-walled, colourless to yellowish in KOH, no encrustations. *Pileipellis* a trichoderm about 250  $\mu$ m thick, composed of more or less vertically arranged hyphae, 5–12  $\mu$ m diam, thin- to slightly thick-walled (up to 0.5  $\mu$ m), colourless to yellowish in KOH; terminal cells 22–96  $\times$  6–10  $\mu$ m, clavate to subcylindrical, with obtuse apex. *Pileus trama* composed of interlaced hyphae 5–13  $\mu$ m diam, thin-walled, yellowish to yellow in KOH. *Stipitipellis* a trichoderm-like structure about 85  $\mu$ m

thick, composed of thin-walled emergent hyphae with subclavate to subcylindrical terminal cells (27–39  $\times$  6–11  $\mu$ m), colourless to yellowish in KOH. *Stipe trama* composed of longitudinally arranged, parallel hyphae 5–15  $\mu$ m wide, cylindrical, thin-walled, yellowish in KOH. *Clamp connections* absent in all tissues.

*Habitat:* Gregarious on the ground in forests dominated by *Pinus massoniana* or fagaceous trees.

*Known distribution:* Southeastern (Fujian Province) and southern China (Guangdong and Hainan Provinces) (Lin *et al.* 2022).

*Holotype:* GDGM87996 (China, Guangdong Province).

*Materials examined:* **China**, Fujian Province, Zhangping City, Xingqiao Town, Chengkou Village, elev. 350 m, 2 Sep. 2009, N.K. Zeng, Zeng665 (FHMU425); Zhangping City, Fuzhige Park, 24 Jul. 2013, N.K. Zeng, Zeng1271, 1271-1 (FHMU3249, 3250); Sanming City, Geshikao National Forest Park, elev. 420 m, 26 Aug. 2007, Y.C. Li, Li1030 (KUN-HKAS53375); Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 9 Sep. 2016, N.K. Zeng, Zeng2913 (FHMU1885).

*Notes:* *Boletellus brunoflavus* was originally described from Guangdong Province of southern China (Lin *et al.* 2022). In the present study, it was also found to be distributed in Hainan and



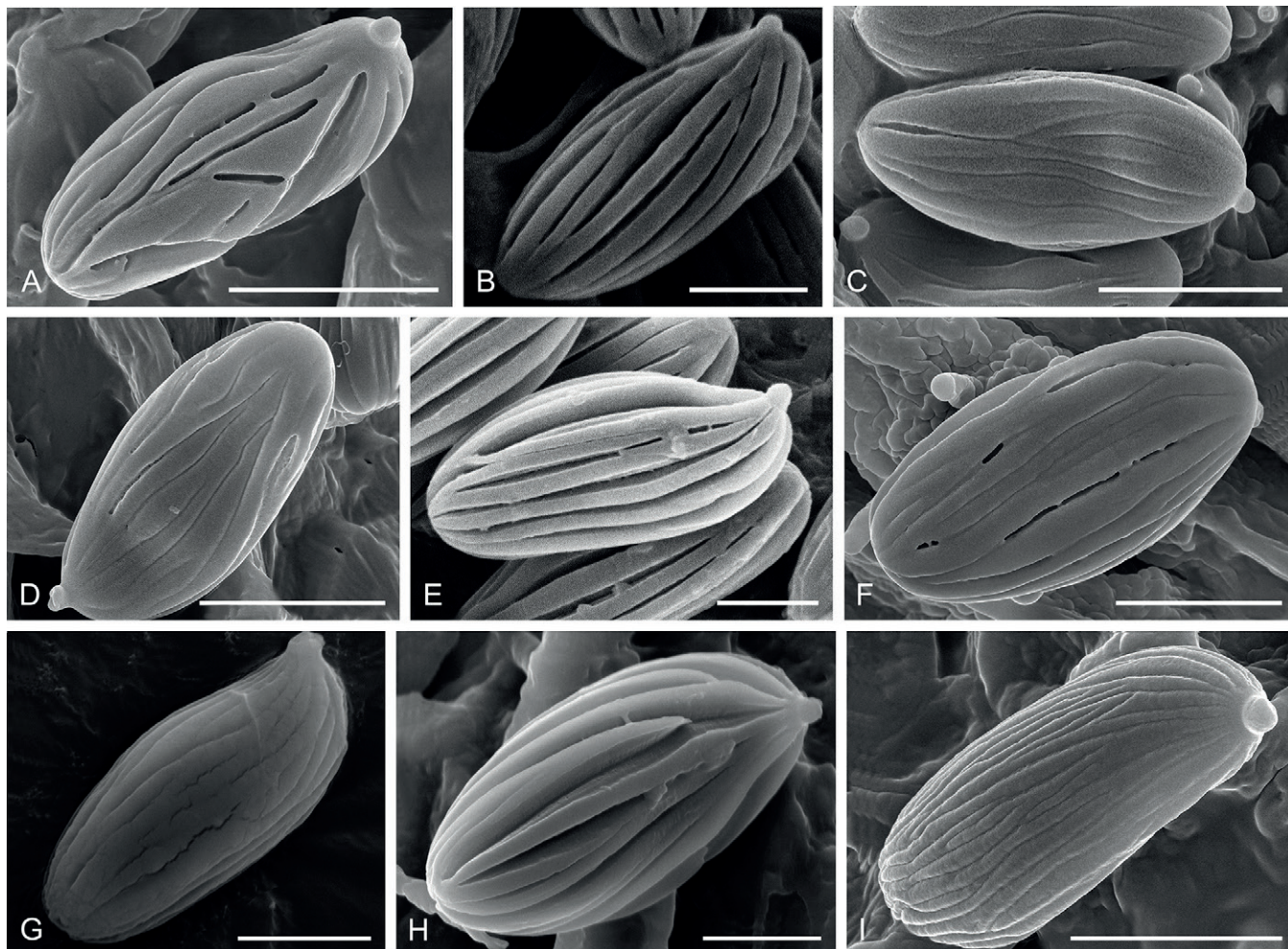


Fig. 25. Basidiospores of *Boletellus* species from herbarium materials under SEM. A. *Bol. aff. putuoensis* (FHMU2168). B. *Bol. areolatus* (FHMU2046). C. *Bol. brunoflavus* (FHMU3249). E. *Bol. emodensis* (FHMU2034). F. *Bol. erythrolepis* (holotype FHMU3255). G. *Bol. fanjingensis* (holotype HMAS45914). H. *Bol. fujianensis* (holotype HMAS45913). I. *Bol. indistinctus* (FHMU936). Scale bars = 5  $\mu$ m. A, C, D, F, I photos by C. Xu; B, E, G, H photos by R. Xue.

Fujian Provinces of China. The species is characterised by a small-sized basidioma, a brown pileus, hymenophore and context turning blue when injured, small, faintly striate basidiospores without cross-striations on ridges, and a pileipellis composed of vertically arranged mostly filamentous hyphae. In the protolog of *Bol. brunoflavus*, the size of basidiospores was described as “6.4–8.2  $\times$  2.3–3.3  $\mu$ m”. According to our specimens, a larger size of basidiospores was observed.

***Boletellus emodensis*** (Berk.) Singer, Ann. Mycol. 40: 19. 1942. MycoBank MB 472279. Figs 19I–L, 23E, 25E, 30.

**Basionym:** *Boletus emodensis* Berk., Hooker's J. Bot. Kew Gard. Misc. 3: 48. 1851.

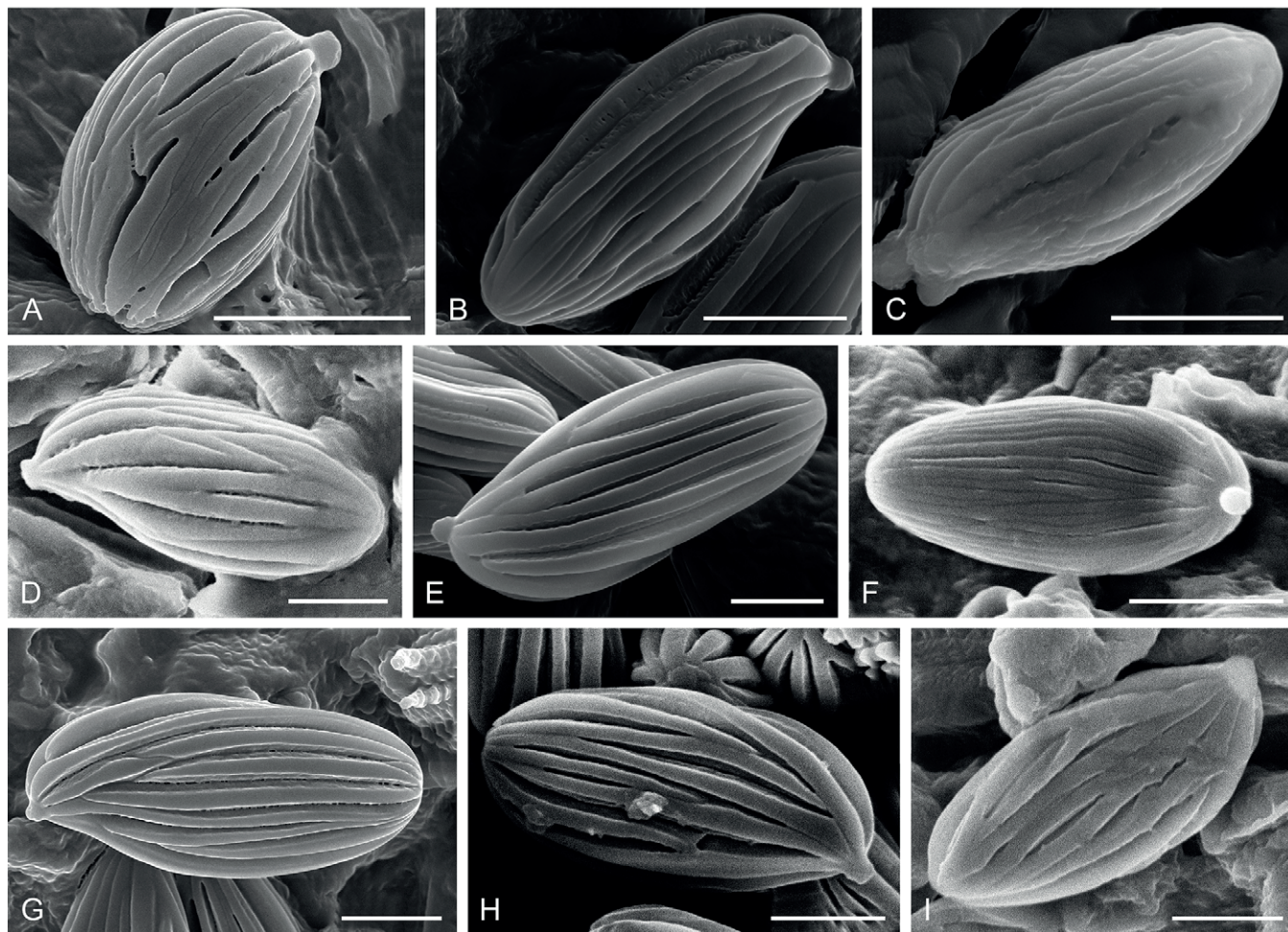
**Synonym:** *Suillus emodensis* (Berk.) Kuntze, Revisio generum plantarum 3 (3): 535. 1898.

**Description:** *Basidiomata* small to medium-sized. *Pileus* 3.5–6.5 cm diam, subhemispherical to convex, then applanate, margin at first extending into a false veil and covering the pores, then splitting radially, appendiculate with false veil remnants; surface dry, reddish brown, purplish red to red, usually fading to pale fawn in age, tomentose when young, then cracking into large, appressed scales; context 0.7–1 cm thick in the centre of the pileus, pale yellow to yellow, turning blue quickly and strongly when injured. *Hymenophore* poroid, depressed around apex of stipe, pores 0.5–2 mm diam, angular, pale yellow to yellow, turning blue strongly

and quickly when injured; tubes 0.6–1.3 cm in length, yellowish, turning blue quickly when injured. *Stipe* 4.5–6  $\times$  0.5–2 cm, central, subcylindrical, sometimes slightly enlarged at base, solid, flexuous; surface dry, fibrous, concolourous with pileus; context pale yellow to yellow, turning blue strongly and quickly when injured; annulus absent; basal mycelium white. *Odour* indistinct.

*Basidia* 28–48  $\times$  12–23  $\mu$ m, clavate, thin- to slightly thick-walled (up to 0.5  $\mu$ m), 4-spored, colourless to yellowish brown in KOH; sterigmata 3–6  $\mu$ m in length. *Basidiospores* [600/30/14] 18.5–21.5  $\times$  7.5–9(–9.5)  $\mu$ m,  $Q = (2.1\text{--})2.5\text{--}2.53\text{--}(2.67)$ ,  $Q_m = 2.31 \pm 0.01$ , yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with longitudinal or oblique ridges, 5–8 ridges visible in lateral view; ridges continuous or forked, united at the apex, projecting 1–1.5  $\mu$ m, with cross-striations on the ridges observed under the light microscope. *Hymenophoral trama* boletoid, composed of hyphae 4–18  $\mu$ m wide, colourless to yellowish in KOH. *Cheilocystidia* 27–53  $\times$  10–18  $\mu$ m, abundant, subfusiform or fusiform, thin-walled, yellowish to yellowish brown in KOH, no encrustations. *Pleurocystidia* 39–80  $\times$  11–18  $\mu$ m, abundant, subfusiform or fusiform, thin- to slightly thick-walled (up to 1  $\mu$ m), colourless to yellowish in KOH, no encrustations. *Pileipellis* a trichoderm about 195  $\mu$ m thick, composed of slightly interlaced, filamentous hyphae, 7–11  $\mu$ m diam, thin- to slightly thick-walled (up to 1  $\mu$ m), yellowish to yellowish brown in KOH; terminal cells 21–65  $\times$  5–12  $\mu$ m, clavate to subcylindrical, with obtuse apex. *Pileus trama* composed of interlaced hyphae 5.5–15  $\mu$ m diam, subcylindrical, thin-walled,





**Fig. 26.** Basidiospores of *Boletellus* species from herbarium materials under SEM. **A.** *Bol. putuoensis* (FHMU3261). **B.** *Bol. rubidus* (holotype KUN-HKAS83069). **C.** *Bol. sinochrysenoides* (holotype FHMU3264). **D, E.** *Bol. squamosus* (**D.** holotype KUN-HKAS4112; **E.** FHMU3266). **F.** *Bol. subglobofus* (holotype FHMU3256). **G.** *Bol. violaceus* (holotype KUN-HKAS10249). **H.** *Bol. yunnanensis* (holotype KUN-HKAS2871). **I.** *Bol. zenghuoxingii* (FHMU1979). Scale bars = 5  $\mu$ m. A, G photos by C. Xu; B–F, H, I photos by R. Xue.

colourless to yellowish in KOH. *Stipitipellis* a trichoderm-like structure about 100  $\mu$ m thick, composed of thin-walled, emergent hyphae with subclavate to subcylindrical terminal cells (26–62  $\times$  5–7.5  $\mu$ m), colourless to yellowish in KOH. *Stipe trama* composed of longitudinally arranged, parallel hyphae 5–15  $\mu$ m wide, cylindrical, thin- to slightly thick-walled (up to 0.5  $\mu$ m), yellowish to yellow in KOH. *Clamp connections* absent in all tissues.

**Habitat:** Solitary or gregarious on the ground, tree stumps or rotten wood in forests dominated by fagaceous trees.

**Known distribution:** Southern (Guangdong and Hainan Provinces), southeastern (Fujian Province), southwestern (Yunnan Province), and central China (Hunan Province) (Zeng & Yang 2011); Japan (Sato & Hattori 2015); India (Berkeley 1851).

**Holotype:** K(M), Hooker 100 (India, West Bengal).

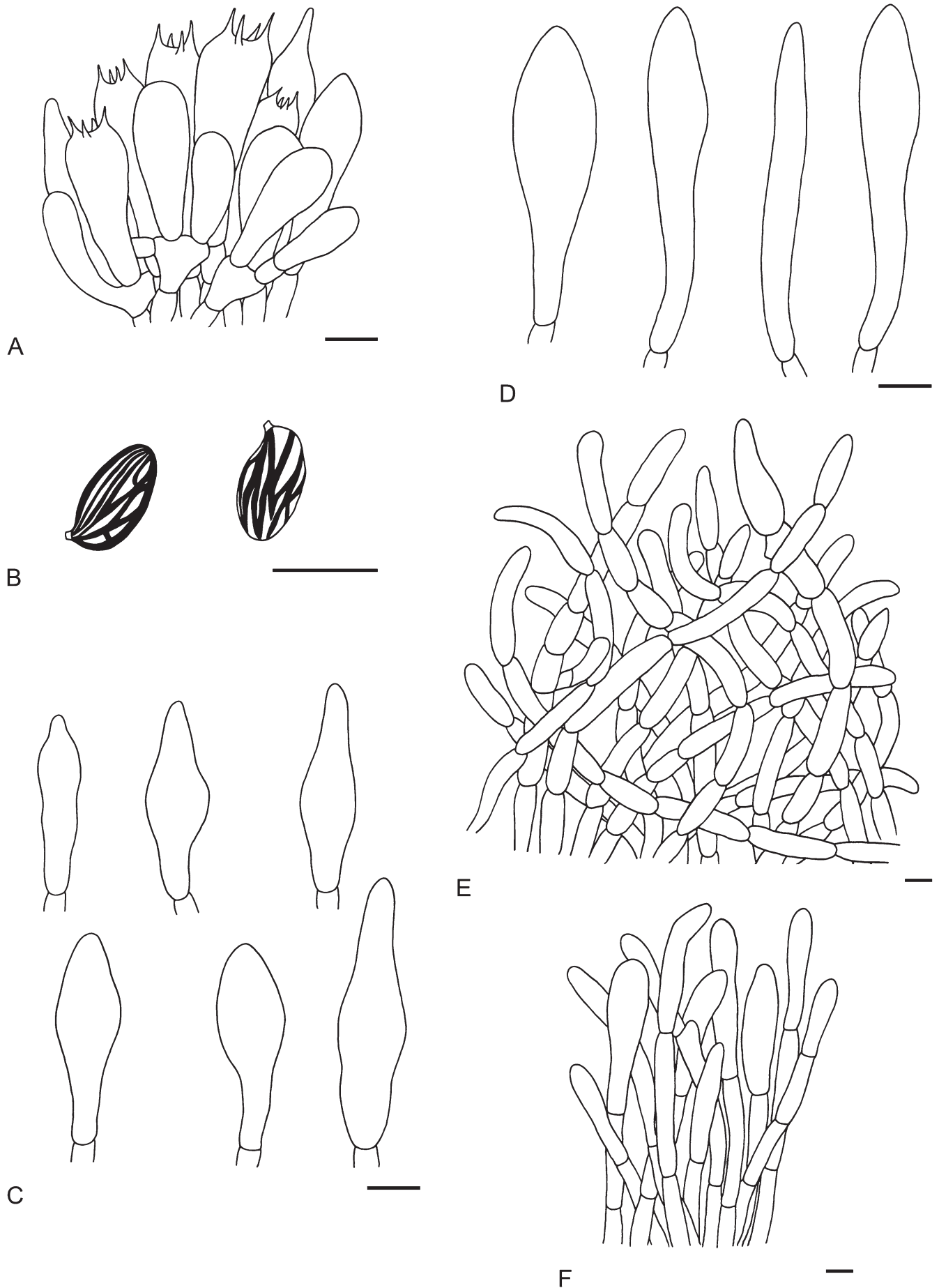
**Materials examined:** **China**, Fujian Province, Zhangping City, Xinqiao Town, Chengkou village, elev. 350 m, 1 Aug. 2013, N.K. Zeng, Zeng1340 (FHMU892); Sanming City, Geshikao Forest Park, elev. 360 m, 16 Aug. 2017, N.K. Zeng, Zeng3243, 3260 (FHMU2204, 2221); Yong'an City, Tianbaoyan National Nature Reserve, elev. 750 m, 17 Aug. 2017, N.K. Zeng, Zeng3284 (FHMU2245); Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 700 m, 3 Aug. 2015, N.K. Zeng, Zeng2488 (FHMU1611); same location, 4 Aug. 2015, N.K. Zeng, Zeng2536

(FHMU1649); same location, 28 May 2017, N.K. Zeng, Zeng3037 (FHMU1998), same location, 26 Jul. 2017, S. Jiang, Jian83 (FHMU3311); same location, 9 Sep. 2016, N.K. Zeng2934 (FHMU1904); same location, 4 Jun. 2017, N.K. Zeng, Zeng3070, 3073 (FHMU2031, 2034), S. Jiang, Jiang54, 63 (FHMU3253, 3254); same location, 5 Jun. 2017, N.K. Zeng, Zeng3103 (FHMU2064); same location, 30 Jul. 2017, N.K. Zeng, Zeng3184, 3191, 3193 (FHMU2145, 2152, 2154); same location, 24 Apr. 2019, R. Xue, Xue10, 13, 14, 17 (FHMU3306, 3307, 3308, 3309); same location, elev. 850 m, 28 Jun. 2018, N.K. Zeng, Zeng3490 (FHMU3252); Bawangling of Hainan Tropical Rainforest National Park, elev. 620 m, 14 Sep. 2019, N.K. Zeng, Zeng4242 (FHMU3310); Guangdong Province, Guangzhou City, Baiyun Mountain, elev. 200 m, 28 May 2013, G. Wu, Wu1107 (KUN-HKAS80481); Hunan Province, Yizhang County, Mangshan National Forest Park, 12 Sep. 2016, G. Wu, Wu1799 (KUN-HKAS99918).

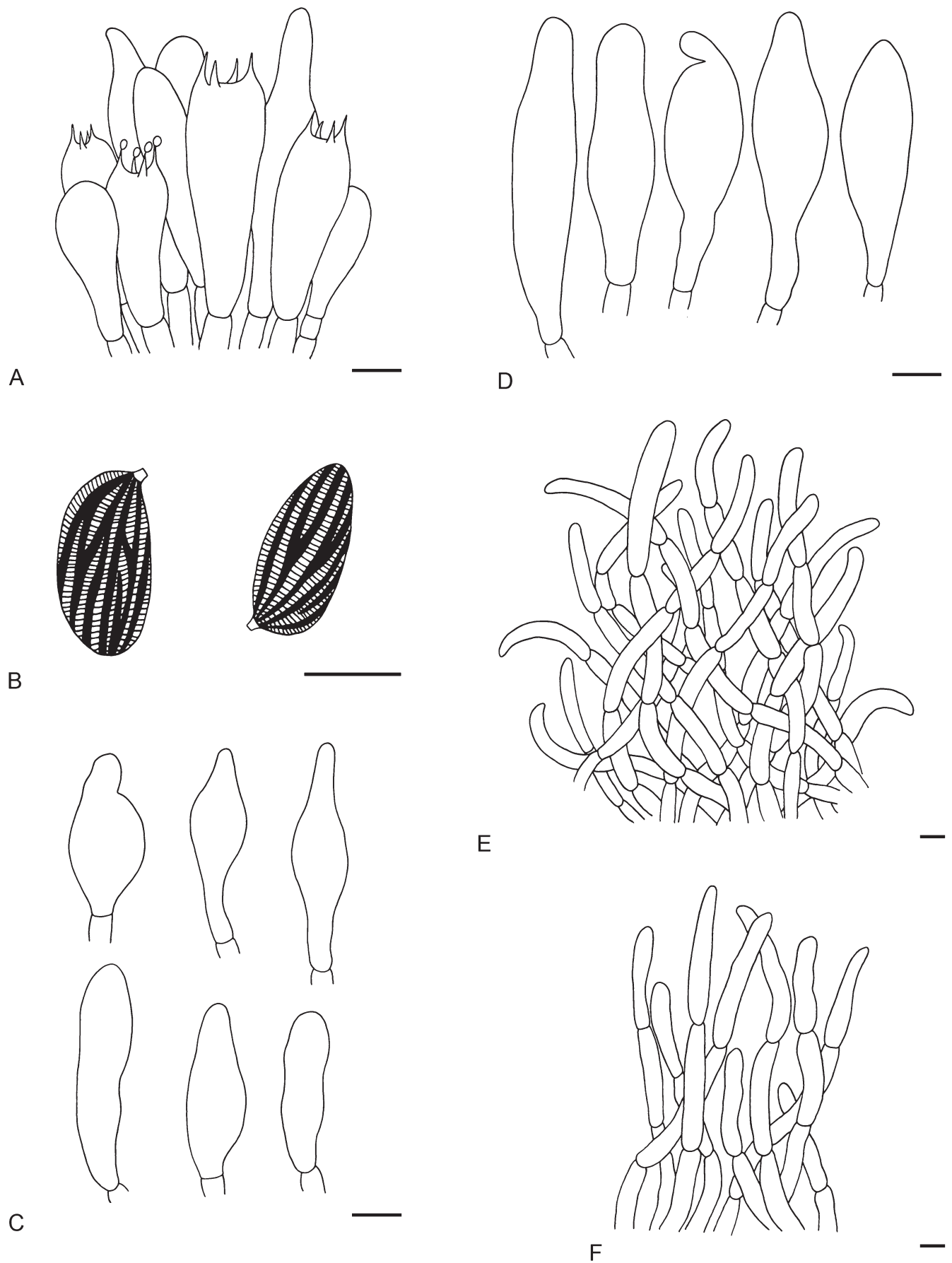
**Notes:** *Boletellus emodensis* was first described from northeastern India (Pegler & Young 1981), then subsequently reported from southeast Asia, east Asia, and Australia (Zeng & Yang 2011, Halling *et al.* 2015), which is characterised by its pileus covered with large, appressed, reddish brown, purplish red to red scales, a yellow context, hymenophore and context turning blue strongly and rapidly when injured, large distinctly striate basidiospores with cross-striations on ridges, and a pileipellis composed of filamentous hyphae.

Currently available data suggest that there are no significant morphological differences between *Bol. emodensis* and Japanese *Bol. aurocontextus* (Zeng & Yang 2011, Halling *et al.* 2015, Sato & Hattori 2015). Moreover, our molecular phylogenetic





**Fig. 27.** Microscopic features of *Boletellus aff. putuoensis* (FHMU2168). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10 µm. Drawings by R. Xue.



**Fig. 28.** Microscopic features of *Boletellus areolatus* (FHMU2046). **A.** Basidia and pleurocystidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10 μm. Drawings by R. Xue.

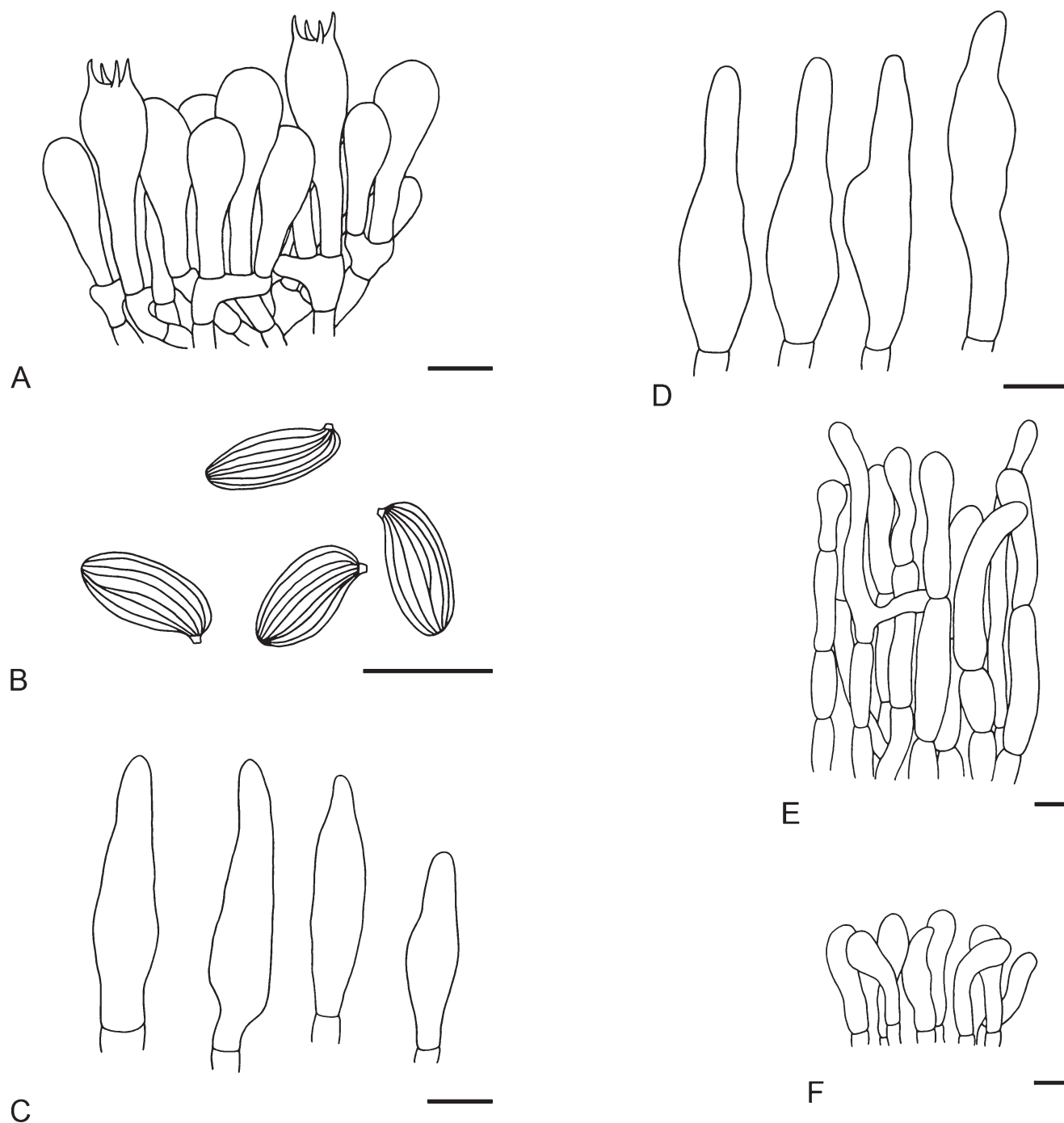


Fig. 29. Microscopic features of *Boletellus brunofflavus* (FHMU3249). A. Basidia. B. Basidiospores. C. Cheilocystidia. D. Pleurocystidia. E. Pileipellis. F. Stipitipellis. Scale bars = 10 µm. Drawings by R. Xue.

analyses indicated that the collections of *Bol. emodensis* from China, the holotype of *Bol. aurocontextus*, and one specimen from northeastern India (type locality of *Bol. emodensis*) labeled as *Boletellus* sp. (Bol-10) form an independent species-level lineage with high statistical support (Fig. 2), which not only further demonstrated the Chinese specimens are true *Bol. emodensis*, but also provided molecular evidence that *Bol. aurocontextus* is a synonym of *Bol. emodensis*.

***Boletellus erythrolepis*** N.K. Zeng, R. Xue, S. Jiang & Zhi Q. Liang, *sp. nov.* MycoBank MB 840068. Figs 20A–E, 23F, 25F, 31.

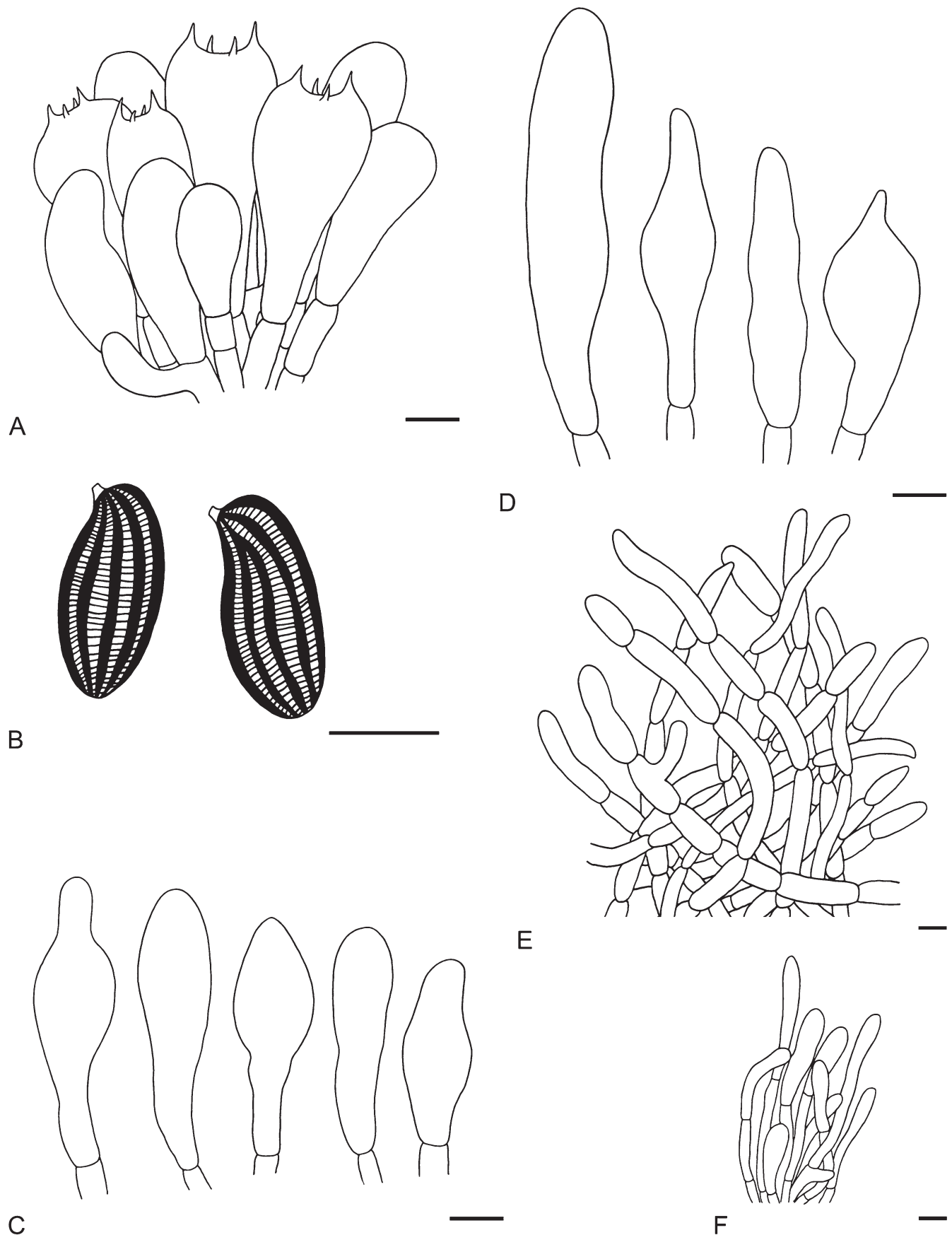
*Etymology:* *erythrolepis* (Lat.), refers to the red scales on the stipe.

*Diagnosis:* Differs from other species of *Boletellus* by a very small basidioma, an olive brown, brownish red to red pileus, a hymenophore surface turning blue, then reddish when injured, a stipe with red scabers, faintly striate basidiospores without cross-striations on ridges, and a pileipellis composed of chains of subglobose, pyriform to broadly subcylindrical cells.

*Typus:* **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 750 m, 5 Jun. 2017, S. Jiang, Jiang78 (**holotype** FHMU3255).

*Additional materials examined:* **China**, Fujian Province, Zhangping County, Xinqiao Town, Chengkou Village, elev. 350 m, 3 Aug. 2013, N.K. Zeng, Zeng1362 (FHMU913); Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 750 m, 5 Jun. 2017, S. Jiang, Jiang78-1, 78-2, 78-3 (FHMU3312, 3313, 3314).





**Fig. 30.** Microscopic features of *Boletellus emodensis* (FHMU2034). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10 µm. Drawings by R. Xue.

**Description:** *Basidiomata* very small-sized. *Pileus* 1.3–2.2 cm diam, subhemispherical to convex, margin decurved; surface dry, olive brown (6C2), brownish red (10C6) to red (9B6), tomentose; context

0.2–0.3 cm thick in the centre of pileus, white (2A1), turning blue (19C6) quickly when injured. *Hymenophore* poroid, depressed around apex of stipe; pores about 0.5 mm diam, angular, yellow

(3A4), turning blue (19C6) quickly, then changing reddish (10A7) slowly when injured; tubes about 0.5 cm in length, yellowish (3A4), turning blue (19C6) quickly when injured. *Stipe* 3.7–4.2 × 0.4–0.8 cm, central, subcylindrical, solid, flexuous; surface dry, greyish red (13B4) to pale red (9B4), covered with purplish red (14C8) to red (10A7) scabers, with longitudinal ridges; context yellow (3A4), turning blue (3A4) quickly when injured; annulus absent; basal mycelium white (1A1). *Odour* indistinct.

*Basidia* 36–48 × 10–16 µm, clavate, 4-spored, colourless to yellowish in KOH; sterigmata 3–4.5 µm in length. *Basidiospores* [60/3/3] 15–19 × (6–)6.5–8(–8.5) µm,  $Q = (2-)2.2-2.85(-3.17)$ ,  $Q_m = 2.49 \pm 0.24$ , yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with shallowly longitudinal ridges, 6–10 ridges visible in lateral view; ridges united at the apex, projecting about 0.5 µm, without cross-striations on the ridges observed under the light microscope. *Hymenophoral trama* boletoid, composed of hyphae 5.5–15 µm wide, colourless in KOH. *Cheilocystidia* 38–56 × 11–16.5 µm, abundant, fusiform, subfusiform or ventricose, thin-walled, colourless to yellow in KOH, no encrustations. *Pleurocystidia* 44–70 × 10–16 µm, abundant, subfusiform or fusiform, colourless to yellow in KOH, no encrustations. *Pileipellis* a trichoderm 200–240 µm thick, composed of chains of subglobose, pyriform to broadly subcylindrical cells up to 20 µm in width arising from filamentous hyphae, thin- to slightly thick-walled (up to 0.5 µm), light yellow to yellow in KOH; terminal cells 11–45 × 8–19 µm, subglobose, pyriform to subcylindrical, with obtuse apex. *Pileus trama* composed of interlaced hyphae 6–17 µm diam, thin- to slightly thick-walled (up to 0.5 µm), colourless in KOH. *Stipitipellis* a trichoderm-like structure 75–95 µm thick, composed of thin-walled emergent hyphae, yellow in KOH, with subclavate, subfusiform or subcylindrical terminal cells (23–58 × 8–17 µm), and usually with clavate, 4-spored basidia. *Stipe trama* composed of longitudinally arranged, parallel hyphae 5.5–12 µm diam, cylindrical, thin- to slightly thick-walled (up to 0.5 µm), colourless in KOH. *Clamp connections* absent in all tissues.

*Habitat*: Solitary or gregarious on the ground in forests dominated by fagaceous trees.

*Known distribution*: Southern (Hainan Province) and southeastern China (Fujian Province).

*Notes*: *Boletellus erythrolepis* is morphologically similar to Australian *Bol. sinapipes*. However, *Bol. sinapipes* has a brown to dark brown pileus, a stipe finely and obscurely subpruinose to finely subtomentose at apex, fibrillose streaked to matted fibrillose below, smaller basidiospores measuring 11.9–15.4 × 5.6–7 µm, and a pileipellis composed of cylindrical hyphae 5–10 µm broad (Halling *et al.* 2015). Phylogenetically, species closely related to *Bol. erythrolepis* was not detected from our current data (Fig. 2).

***Boletellus fanjingensis*** H.A. Wen, Acta Mycol. Sin. 4: 224. 1985. MycoBank MB 103091. Figs 20F, G, 23G, 25G, 32.

Macroscopic descriptions are from the protologue (Wen 1985); microscopic descriptions are from our examinations.

*Description*: “*Pileus* 2.0–4.0 cm *latus*, *hemisphaerico-applanatus*, *ravido-badius vel rabello-brunneus*, *velutinus*, *rimosus*, *sine velo*. *Hyphis cuticulis subflavis vel flavido-badiis*, *sine fibula*. *Came rubella*, *in vulnore cyanesceni*, *dein rufesceti*. *Tubuli superficies flavo-viridi*, *in vulnore cyanesceni*, *dein rufesceti*, *adnexi vel*

*subdecurrentes ad stipitem*. *Pori angulares*, *2 in uno mm*. *Stipes centralis*, *1.5–3.5 × 0.2–0.3 cm*, *argillaceus*, *verruculosus*.”

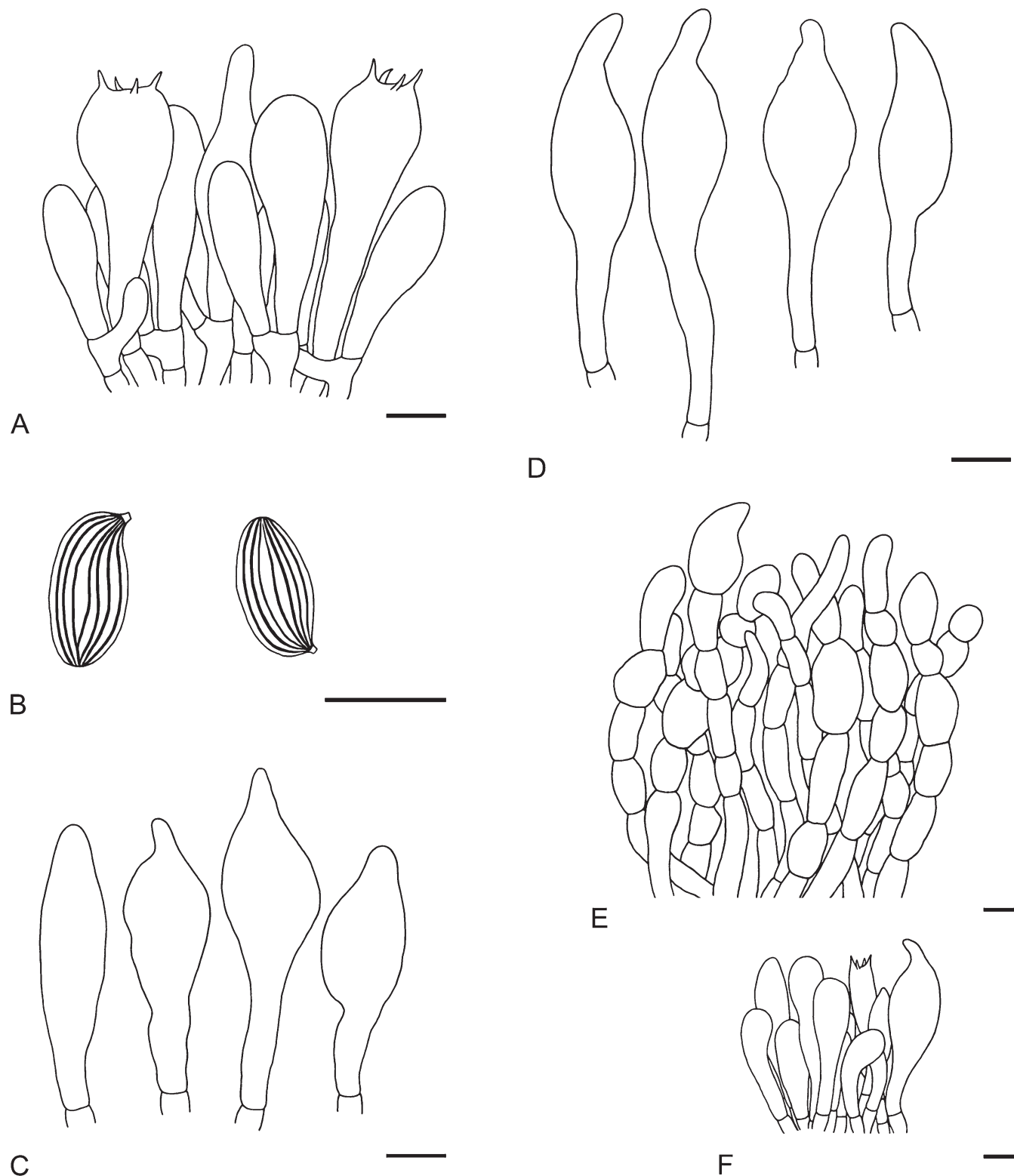
*Basidia* 30–41 × 11–15 µm, clavate, thin-walled, 4-spored, colourless to yellowish in KOH; sterigmata 3–5 µm in length. *Basidiospores* [20/1/1] 12.5–15.5 × 6.5–7.5 µm,  $Q = 1.8-2.08$ ,  $Q_m = 1.96 \pm 0.08$ , yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with longitudinal ridges, 5–7 ridges visible in lateral view; ridges continuous or forked, united at the apex, lacking cross-striations on the ridges observed under the light microscope. *Hymenophoral trama* boletoid, composed of hyphae 4–10 µm wide, yellowish to yellow in KOH. *Cystidia* 35–69 × 8–19 µm, abundant, subfusiform or fusiform, thin-walled, yellowish to yellow in KOH, no encrustations. *Pileipellis* a trichodermium composed of interlaced, filamentous hyphae, 4–7 µm diam, thin-walled, yellowish in KOH; terminal cells 30–60 × 4–9 µm, clavate to subcylindrical, with obtuse or acute apex. *Pileus trama* composed of interlaced hyphae 6–13 µm diam, thin-walled, yellowish to yellow in KOH.

*Habitat*: Scattered on the ground in forests dominated by broad-leaved trees.

*Known distribution*: Southwestern China (Guizhou Province).

*Material examined*: **China**, Guizhou Province, Fanjingshan National Nature Reserve, Macaohe, elev. 750 m, 17 Aug. 1982, Y.C. Zong & H.A. Wen, Wen037 (**holotype** HMAS45914).

*Notes*: *Boletellus fanjingensis*, originally described from Guizhou Province of southwestern China (Wen 1985), is a poorly known species. In the present study, the holotype of the species was re-examined, which is characterised by a small, tomentose, brown to reddish brown pileus, hymenophore and context turning blue, then reddish when injured, distinctly striate basidiospores without cross-striations on ridges, and a pileipellis composed of filamentous hyphae. *Boletellus fanjingensis* is morphologically similar to *Bol. brunoflavus*, *Bol. chrysenteroides*, *Bol. fujianensis*, *Bol. nordestinus*, *Bol. pseudochrysenteroides*, *Bol. putuoensis*, *Bol. shoreae*, *Bol. sinapipes*, and *Bol. wenshanensis*. However, *Bol. brunoflavus* has smaller basidiospores measuring 10–12.5 × 4–5 µm with faint ridges (see above); *Bol. chrysenteroides* has slightly narrower basidiospores measuring 12–16 × 4.6–7.5 µm, a pileipellis with cystidioid terminal cells and inflated sub-terminal elements (12–20 µm broad and 15–30 µm long), and a distribution in North America (Smith & Thiers 1971); *Bol. fujianensis* has larger basidiospores measuring 19–23.5 × 10.5–12 µm with cross-striations on ridges observed under the light microscope (see below); *Bol. nordestinus* has non-cyanescent hymenophore and context, shorter basidiospores measuring 8–10 × 6–7 µm, a pileipellis composed of inflated hyphae, and a distribution in South America (Magnago *et al.* 2019); *Bol. pseudochrysenteroides* has a dark rose red pileus, smaller basidiospores measuring 11–14 × 5.5–7 µm, and a distribution in North America (Smith & Thiers 1971); *Bol. putuoensis* has shorter basidiospores measuring 9–12 × 6–7.5 µm, and a pileipellis composed of inflated hyphae (Xu *et al.* 2022); *Bol. shoreae* has shorter basidiospores measuring 8–11 × 5.3–7.6 µm, and it is associated with trees of *Dipterocarpaceae* (Parihar *et al.* 2018); *Bol. sinapipes* has a mustard brown-coloured tomentum at the base of the stipe, and a distribution in Australia (Halling *et al.* 2015); *Bol. wenshanensis* has a pileus without reddish tinge, and the hymenophore and context turning blue (not changing reddish further) when injured (Zhang & Wu 2022).



**Fig. 31.** Microscopic features of *Boletellus erythrolepis* (holotype FHMU3255). **A.** Basidia and pleurocystidium. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10 µm. Drawings by R. Xue.

***Boletellus fujianensis*** H.A. Wen, Acta Mycol. Sin. 4: 223. 1985. MycoBank MB 103092. Figs 20H, I, 23H, 25H, 33.

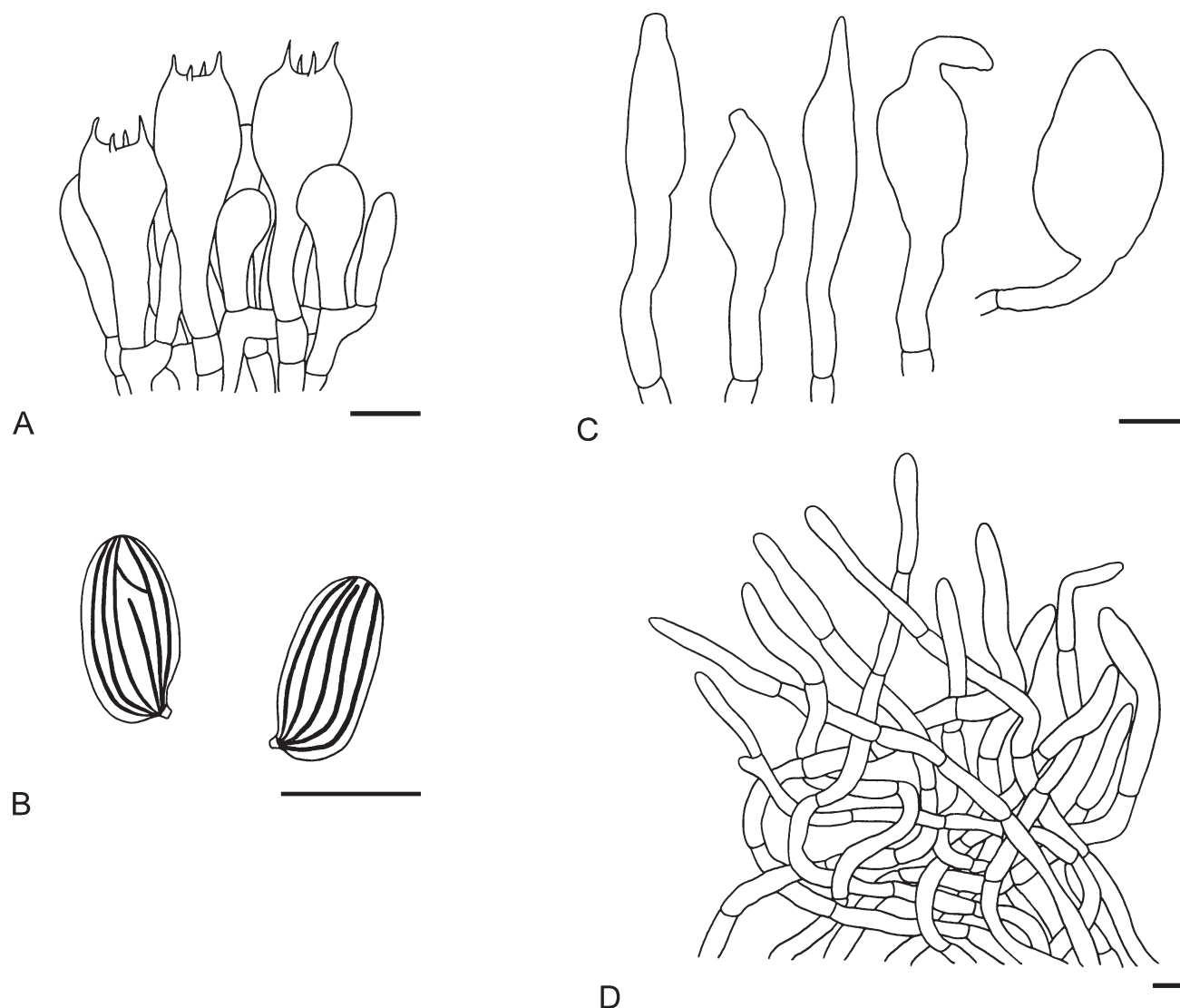
Macroscopic descriptions are from the protologue (Wen 1985); microscopic descriptions are from our examinations.

**Description:** "Pileus 4.5 cm latus, applanatus, subviscosus, flavor-badius, squamis velutinis brunneis, sine velo, hyphis cuticulis intertextis, cellulis extremis inflatis, 5.2–8.4 µm crassis,

KOH flavescentibus vel brunneis per microscopium, sine fibula, carneluteola, immutabili in vulnere. Tubuli flavi, adnexi. Pori angulares, 1–2 in uno mm. Hymenia flavo-brunnea in solutionem KOH. Stipes 4.5 cm longus, 0.5 cm crassus."

**Basidia** 36–50 × 15–20 µm, clavate, thin-walled, 4-spored, yellowish in KOH; sterigmata 4.5–7 µm in length. **Basidiospores** [20/1/1] 19–23.5 × 10.5–12 µm, Q = 1.75–2.05, Qm = 1.9 ± 0.09, yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with longitudinal or oblique ridges, 7–9 ridges visible in lateral view; ridges





**Fig. 32.** Microscopic features of *Boletellus fanjingensis* (holotype HMAS45914). **A.** Basidia. **B.** Basidiospores. **C.** Cystidia. **D.** Pileipellis. Scale bars = 10 µm. Drawings by R. Xue.

continuous or forked, projecting 1–1.5 µm, with cross-striations on the ridges observed under the light microscope. *Hymenophoral trama* boletoid, composed of hyphae 6–12 µm wide, colourless to yellow in KOH. *Cystidia* 52–78 × 13–21 µm, subfusiform or ventricose, thin-walled, yellow in KOH, no encrustations. *Pileipellis* a trichoderm composed of more or less vertically arranged, filamentous hyphae, 5–9 µm diam, thin-walled, yellow in KOH; terminal cells 30–70 × 5–10 µm, clavate to subcylindrical, with acute apex. *Pileus trama* composed of interlaced hyphae 5–16 µm diam, thin-walled, yellowish to yellow in KOH.

**Habitat:** Solitary on the base of stumpage of *Pinus massoniana*.

**Known distribution:** Southeastern China (Fujian Province).

**Material examined:** **China**, Fujian Province, Sanming City, Yangshan, 11 Jul. 1974, X.L. Mao, Q.M. Ma & C.R. Jiang, Jiang187 (**holotype** HMAS45913).

**Notes:** *Boletellus fujianensis*, firstly described from Fujian Province of southeastern China (Wen 1985), is also a poorly known species. In the present study, the holotype of the species was re-examined, which is characterised by a small pileus covered with brown scales,

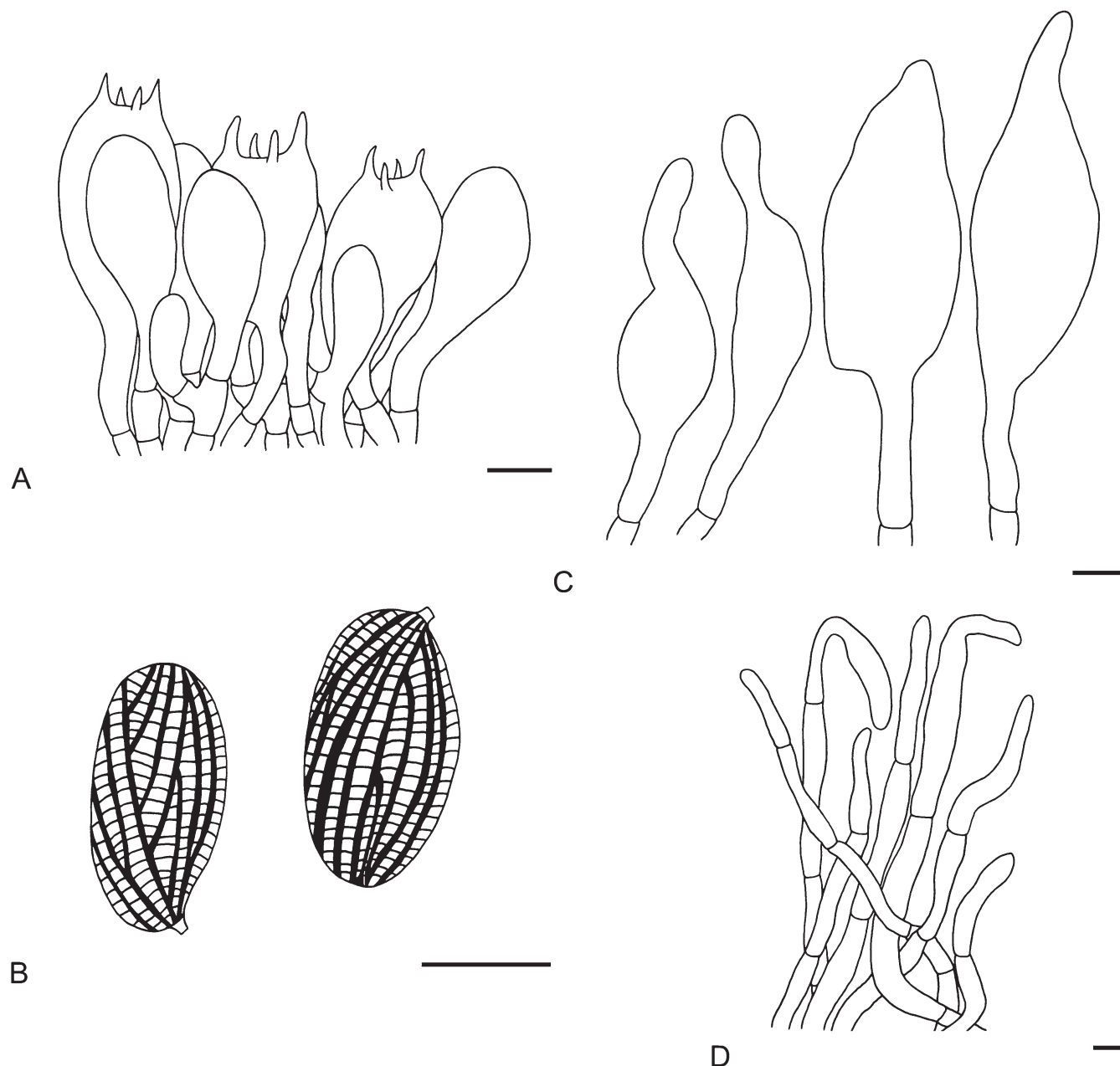
hymenophore and context unchanging in colour when injured, large distinctly striate basidiospores with cross-striations on ridges, and a pileipellis composed of filamentous hyphae with acute apex of terminal cells. *Boletellus fujianensis* is morphologically similar to *Bol. brunoflavus*, *Bol. chrysenteroides*, *Bol. nordestinus*, *Bol. pseudochrysenteroides*, *Bol. putuoensis*, *Bol. shoreae*, *Bol. sinapipes*, and *Bol. wenshanensis*. However, all of them have smaller basidiospores measuring 10–12.5 × 4–5 µm, 12–16 × 4.6–7.5 µm, 8–10 × 6–7 µm, 11–14 × 5.5–7 µm, 9–12 × 6–7.5 µm, 8–11 × 5.3–7.6 µm, 11.9–15.4 × 5.6–7 µm, and 12–15.5 × 6–8 µm, respectively (Smith & Thiers 1971, Halling *et al.* 2015, Parihar *et al.* 2018, Magnago *et al.* 2019, Lin *et al.* 2022, Xu *et al.* 2022, Zhang & Wu 2022). Moreover, *Bol. chrysenteroides* has a pileipellis with cystidioid terminal cells and inflated sub-terminal elements (12–20 µm broad and 15–30 µm long), and a distribution in North America (Smith & Thiers 1971); *Bol. nordestinus* has a pileipellis composed of inflated hyphae, and a distribution in South America (Magnago *et al.* 2019); *Bol. pseudochrysenteroides* has a dark rose red pileus, and a distribution in North America (Smith & Thiers 1971); *Bol. putuoensis* has a pileipellis composed of inflated hyphae (Xu *et al.* 2022); *Bol. sinapipes* has a mustard brown-coloured tomentum at the base of the stipe, basidiospores without cross-striations on ridges, and a distribution in Australia (Halling *et al.* 2015).

***Boletellus indistinctus*** G. Wu *et al.*, Fungal Diversity 81: 61. 2016. MycoBank MB 818395. Figs 21A–D, 23I, 25I, 34.

**Description:** *Basidiomata* small, middle to large-sized. *Pileus* 3.5–12 cm diam, subhemispherical to convex, then applanate, margin decurved; surface dry, tomentose, pinkish to pink; context 1–2.5 cm thick in the centre of the pileus, yellowish white to yellowish, turning blue quickly when injured. *Hymenophore* poroid, nearly adnate to slightly decurrent; pores 0.25–2 mm diam, angular to round, yellowish to yellow, turning blue quickly when injured; tubes 0.2–0.9 cm in length, yellowish to yellow, turning blue quickly when injured. *Stipe* 5–14 × 0.9–2.5 cm, central, subcylindrical, solid; surface dry, sometimes covered with reticulations, concolourous with pileus, but yellow near the apex; context pale yellow, turning blue quickly when injured; annulus absent; basal mycelium white. *Odour* indistinct.

*Basidia* 30–40 × 10–12 µm, clavate, thin-walled, 4-spored, colourless to yellow in KOH; sterigmata 3–5 µm in length. *Basidiospores* [560/28/9] (10.5–)11–11.5(–12) × 4.5–5.5(–6) µm,  $Q = (1.83\text{--})1.91\text{--}2.63$ ,  $Q_m = 2.21 \pm 0.01$ , yellowish to yellowish

brown in KOH, ellipsoid to subfusiform, with faintly longitudinal ridges, united at the apex, 10–12 ridges visible in lateral view. *Hymenophoral trama* boletoid, composed of hyphae 5–15 µm wide, colourless to yellowish in KOH. *Cheilocystidia* 28–50 × 6–8.5 µm, abundant, subfusiform or fusiform, thin-walled, colourless in KOH, no encrustations. *Pleurocystidia* 37–60 × 7–10 µm, abundant, subfusiform or fusiform, thin-walled, colourless to yellowish in KOH, no encrustations. *Pileipellis* a trichoderm about 200 µm thick, composed of slightly interlaced, filamentous hyphae, 5–8 µm diam, thin-walled, yellow to yellowish brown in KOH; terminal cells 32–75 × 5.5–8 µm, clavate to subcylindrical, with obtuse apex. *Pileus trama* composed of interlaced hyphae 4–12 µm diam, colourless in KOH. *Stipitipellis* a trichoderm-like structure about 100 µm thick, composed of thin-walled emergent hyphae with subclavate to subcylindrical terminal cells (25–43 × 5–11 µm), yellowish to yellowish brown in KOH. *Stipe trama* composed of longitudinally arranged, parallel hyphae 5–16 µm wide, cylindrical, thin- to slightly thick-walled (up to 0.5 µm), colourless to yellowish in KOH. *Clamp connections* absent in all tissues.



**Fig. 33.** Microscopic features of *Boletellus fujianensis* (holotype HMAS45913). **A.** Basidia. **B.** Basidiospores. **C.** Cystidia. **D.** Pileipellis. Scale bars = 10 µm. Drawings by R. Xue.



**Habitat:** Gregarious on the ground in forests dominated by fagaceous trees.

**Known distribution:** Southern (Guangdong and Hainan Provinces), southeastern (Fujian Province), and southwestern China (Yunnan Province) (Wu *et al.* 2016).

**Holotype:** KUN-HKAS77623 (China, Guangdong Province).

**Materials examined:** **China**, Guangdong Province, Renhua County, Danxia National Nature Reserve, 27 Jul. 2019, N.K. Zeng, Zeng4134, 4135, 4137 (FHMU3320, 3321, 3322); Fujian Province, Zhangping City, Xinqiao Town, Chengkou Village, elev. 360 m, N.K. Zeng, Zeng649 (FHMU412); same location, 30 Jul. 2013, N.K. Zeng, Zeng1333 (FHMU886); same location, 7 Aug. 2013, N.K. Zeng, Zeng1388, 1393 (FHMU936, 940); same location, 14 Aug. 2014, N.K. Zeng, Zeng1624 (FHMU1088); same location, 21 Aug. 2017, N.K. Zeng, Zeng3298 (FHMU2259); same location, 22 Aug. 2017, N.K. Zeng, Zeng3308 (FHMU2269); Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, 1 Aug. 2015, N.K. Zeng, Zeng2470 (FHMU1596); same location, 17 May 2019, Y.Q. Fu, Fu91, 99 (FHMU3316, 3317); same location, elev. 650 m, 4 Jun. 2017, N.K. Zeng, Zeng3067 (FHMU2028); same location, 30 Jul. 2017, N.K. Zeng, Zeng3188 (FHMU2149); same location, 24 Apr. 2019, R. R. Xue and N.K. Zeng, Xue3, Zeng4000, 4002 (FHMU3315, 3318, 3319); Yunnan Province, Yuxi City, Eshan County, bought from market, 15 Jul. 2018, N.K. Zeng, Zeng3652 (FHMU2852); Xishuangbanna Dai Autonomous Prefecture, Mengla County, elev. 1 039 m, 6 Jul. 2014, L.H. Han, Han381 (KUN-HKAS84677).

**Notes:** *Boletellus indistinctus* was originally described from Guangdong Province of southern China, and also reported to distribute in Fujian Province of southeastern China (Wu *et al.* 2016), then it was confirmed to distribute in Hainan Province, tropical China (Zeng & Jiang 2020). In the present study, it was also found to be distributed in Yunnan Province of southwestern China. The species is characterised by its rose-red pileal surface, cyanescent hymenophore and context, faintly longitudinally striate basidiospores, and a pileipellis composed of filamentous hyphae.

***Boletellus puniceus*** (W.F. Chiu) X.H. Wang & P.G. Liu, Mycotaxon 84: 128. 2002. MycoBank MB 428946.

**Basionym:** *Boletus puniceus* W.F. Chiu, Mycologia 40: 217. 1948.  
**Synonyms:** *Xerocomus puniceus* (W.F. Chiu) F.L. Tai, Syll. fung. Sinicorum: 815. 1979.

*Boletus megasporus* M. Zang, Acta Microbiol. Sin. 20: 30. 1980.

**Known distribution:** Southwestern (Yunnan Province) and southern China (Guangdong Province) (Chiu 1948, Wang & Liu 2002, Wu *et al.* 2016).

**Holotype:** KUN-HKAS37152 (China, Yunnan Province).

**Notes:** *Boletellus puniceus* was originally described from Yunnan Province, southwestern China by Chiu (1948). It was first classified in the genus *Boletus* and later transferred to *Xerocomus* (Tai 1979). One recent study indicated it is a member of *Boletellus* (Wang & Liu 2002). Judging from morphological features and geographical distributions provided by Wu *et al.* (2016), two collections labelled as *Bol. obscurecoccineus* from subtropical China including Yunnan Province, were represent true *Bol. puniceus*. *Boletellus obscurecoccineus*, originally described from Indonesia, was not confirmed to be distributed in China.

***Boletellus putuoensis*** N.K. Zeng *et al.*, Phytotaxa 554: 156. 2022. MycoBank MB 840074. Figs 21E–G, 24A, 26A, 35.

**Description:** *Basidiomata* small-sized. *Pileus* 1.7–4.8 cm diam, subhemispherical to convex when young, then applanate, margin decurved; surface dry, tomentose, brown to dark brown; context 0.2–0.5 cm thick in the centre of the pileus, yellow, turning blue quickly when injured. *Hymenophore* poroid, depressed around apex of stipe; pores angular, 0.3–0.8 mm diam, pale yellow to yellow, turning blue quickly when injured; tubes 0.3–0.6 cm in length, pale yellow to yellow, turning blue quickly then blackening when injured. *Stipe* 3–5.5 × 0.5–4 cm, central, subcylindrical, solid, sometimes slightly enlarged at base; surface dry, covered with brown to dark brown scabers; context pale yellow, but light brown at base, unchanging in colour when injured; annulus absent; basal mycelium white. *Odour* indistinct.

*Basidia* 24–50 × 13–19 µm, clavate, thin-walled, 4-spored, colourless to yellow in KOH; sterigmata 3.5–5.5 µm in length. *Basidiospores* [80/4/4] (8.5–)9–12(–12.5) × 6–7.5 µm, Q = (1.27–)1.29–1.92(–2.08), Qm = 1.51 ± 0.17, yellowish to yellowish brown in KOH, subglobose to ellipsoid, with 5–8 longitudinal or oblique ridges visible in lateral view, ridges continuous or forked, rarely not continuous, projecting 0.8–1 µm, united at the apex, lacking cross-striations observed under the light microscope. *Hymenophoral trama* boletoid, composed of hyphae 5–13 µm wide, colourless in KOH. *Cheilocystidia* 38–64 × 10–18 µm, abundant, subfusiform or fusiform, thin-walled, colourless to yellow in KOH, no encrustations. *Pleurocystidia* 54–90 × 11–17.5 µm, abundant, fusiform, subfusiform or ventricose, thin-walled, colourless to yellow in KOH, no encrustations. *Pileipellis* a trichoderm about 150 µm thick, composed of more or less vertically arranged hyphae, expanded to 20 µm in width, thin-walled, colourless to yellowish in KOH; terminal cells 32–75 × 10–17 µm, clavate to subcylindrical, with acute apex. *Pileus trama* composed of interlaced hyphae 4–18 µm diam, subcylindrical, thin-walled, yellowish in KOH. *Stipitipellis* a trichoderm-like structure about 60 µm thick, composed of colourless to yellow in KOH, thin-walled emergent hyphae with subclavate, subfusiform or subcylindrical terminal cells (21–38 × 8–14 µm), and with clavate, 4-spored basidia. *Stipe trama* composed of longitudinally arranged, parallel hyphae 5–15 µm diam, cylindrical, thin-walled, light yellow in KOH. *Clamp connections* absent in all tissues.

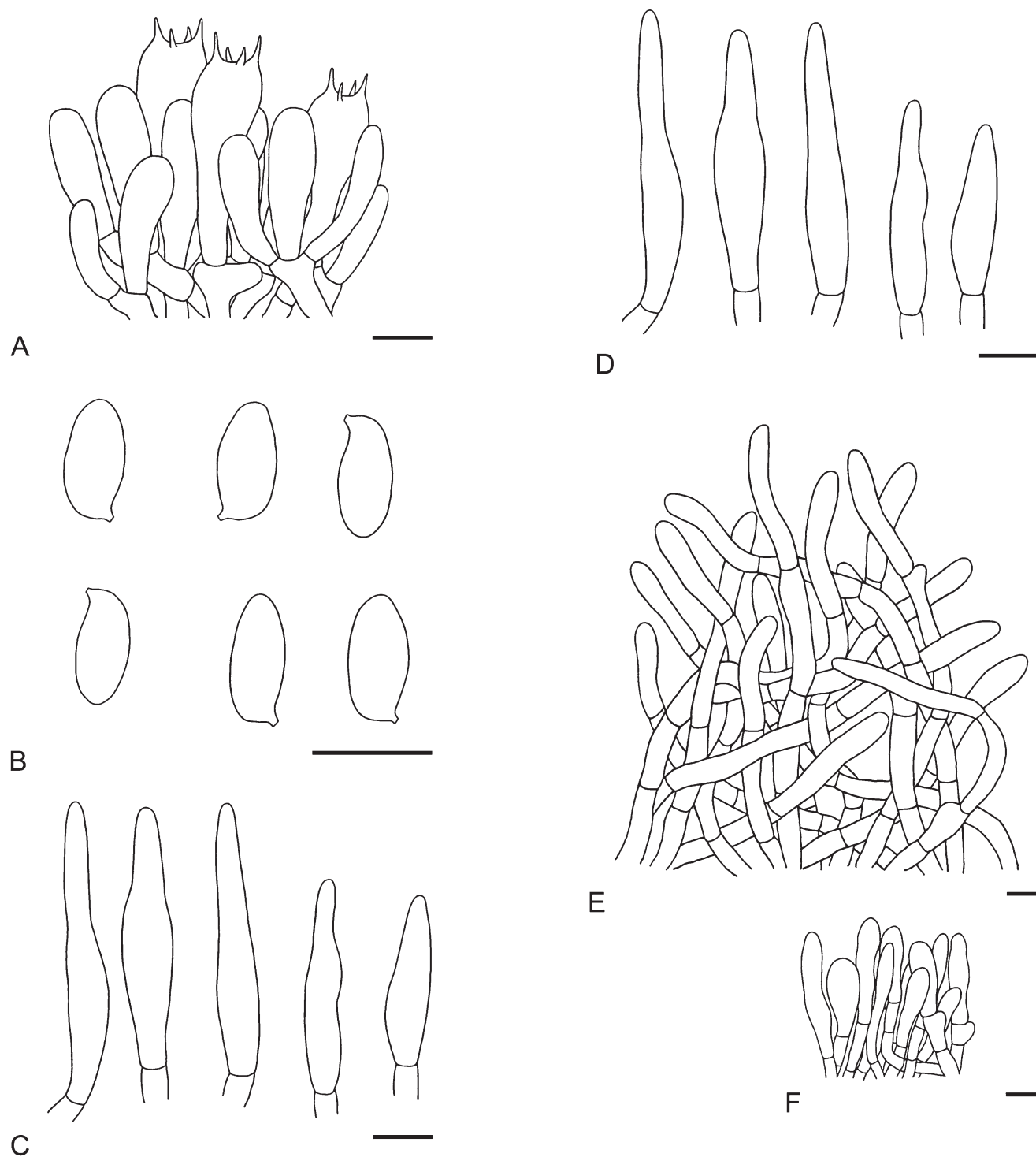
**Habitat:** Solitary on the ground in forests dominated by fagaceous trees.

**Known distribution:** Southern (Guangdong and Hainan Provinces) and eastern China (Zhejiang Province) (Xu *et al.* 2022).

**Holotype:** FHMU6907 (China, Zhejiang Province).

**Materials examined:** **China**, Guangdong Province, Shaoguan City, Renhua County, Danxiashan National Nature Reserve, elev. 350 m, 4 Jun. 2019, N.K. Zeng, Zeng4070, 4091, 4094 (FHMU3260, 3262, 3263); Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 620 m, 30 Jul. 2017, N.K. Zeng, Zeng3186 (FHMU2147).

**Notes:** *Boletellus putuoensis* was originally described from Zhejiang Province of eastern China, and also reported to be distributed in Guangdong Province of southern China (Xu *et al.* 2022). In the present study, it was also distributed in Hainan Province, tropical China. The species is characterised by a very small to small-sized basidioma, a brown to dark brown pileus, a stipe covered with brown to dark brown scabers, cyanescent hymenophore and context, small basidiospores without cross-striations on ridges, and a pileipellis composed of inflated hyphae. According to our new



**Fig. 34.** Microscopic features of *Boletellus indistinctus* (FHMU2269). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10 µm. Drawings by R. Xue.

specimens, the yellow pileal context was observed, while it was described as “white” in the protologue.

***Boletellus rubidus*** N.K. Zeng, R. Xue, Y.J. Hao & Zhi Q. Liang, *sp. nov.* MycoBank MB 840069. Figs 21H, I, 24B, 26B, 36.

*Etymology:* *rubidus* (Lat.), refers to the dark red pileus.

*Diagnosis:* Differs from other species of *Boletellus* by a pileus densely covered with pink, brownish red, red to dark red, hairy, appressed squamules, a white context, small, distinctly striate basidiospores with cross-striations on ridges, and a pileipellis

composed of filamentous hyphae with terminal cells sometimes expanded to 19 µm wide.

*Typus:* **China**, Yunnan Province: Dali Prefecture, Nanjian Yi Autonomous County, Wuliangshan Town, Wuliangshan National Nature Reserve, elev. 2 229 m, 2 Aug. 2014, Y.J. Hao, Hao1278 (**holotype** KUN-HKAS83069).

*Additional materials examined:* **China**, Yunnan Province, Yongping County, roadside of 320 National Road, 30 Jul. 2009, Q. Cai, Cai46 (KUN-HKAS58713); Baoshan City, Baihualing, elev. 1 950 m, 9 Jul. 2018, Y.G. Fan, Fan2795 (FHMU3267).



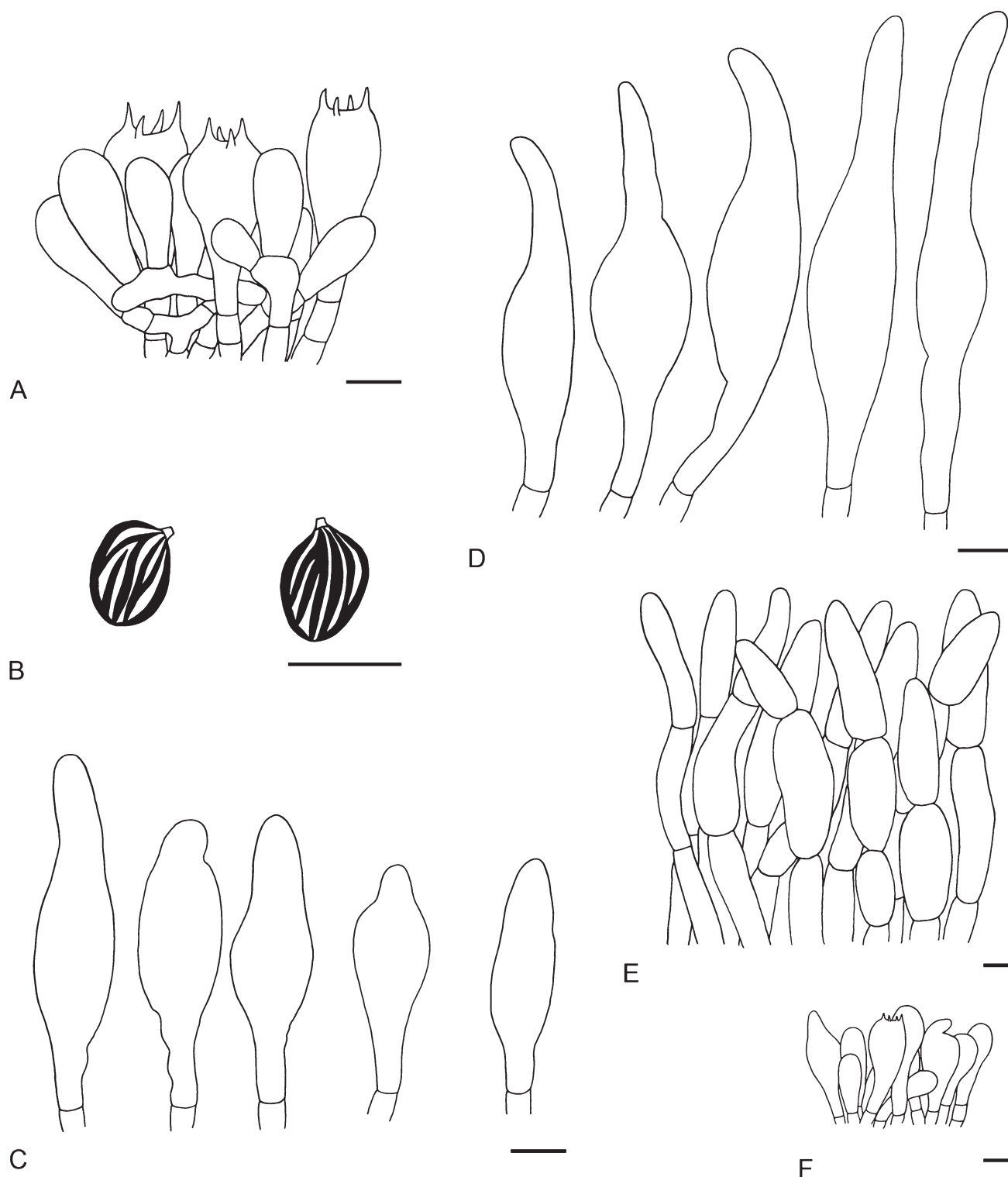


Fig. 35. Microscopic features of *Boletellus putuoensis* (FHMU3261). A. Basidia. B. Basidiospores. C. Cheilocystidia. D. Pleurocystidia. E. Pileipellis. F. Stipitipellis. Scale bars = 10 µm. Drawings by R. Xue.

**Description:** *Basidiomata* medium to large-sized. *Pileus* 5–9 cm diam, subhemispherical to convex, then applanate, margin at first extending into a false veil and covering the pores, then splitting radially, appendiculate with false veil remnants; surface dry, densely covered with pink (7A4), brownish red (10C6), red (10A8) to dark red (11E8), hairy, appressed squamules; context about 0.8 cm thick in the centre of the pileus, white (1A1), turning blue (19C6) quickly when injured. *Hymenophore* poroid, depressed around apex of stipe, pores 0.5–2 mm diam, angular, yellow (4A5), turning blue (19C6) quickly when injured; tubes about 1.7 cm in length,

yellow (4A5), turning blue (19C6) quickly when injured. *Stipe* 11–13 × 1–1.5 cm, central, subcylindrical, solid, flexuous; surface dry, fibrous, light pink (7A2) to pink (7A4), with longitudinal ridges; context white (1A1), turning blue (19C6) quickly when injured; annulus absent; basal mycelium white (1A1). *Odour* indistinct.

*Basidia* 31–48 × 13–17 µm, clavate, thin-walled, 4-spored, colourless to yellowish in KOH; sterigmata 3–5 µm in length. *Basidiospores* [20/2/2] 15–19.5 × 7–9 µm, Q = 1.94–2.44, Qm = 2.11 ± 0.12, yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with longitudinal or oblique ridges, 5–8 ridges visible in

lateral view; ridges continuous or forked, projecting 0.5–1 µm, with cross-striations on the ridges observed under the light microscope. *Hymenophoral trama* boletoid, composed of hyphae 5–15 µm wide, colourless in KOH. *Cheilocystidia* 28–41 × 8–11 µm, abundant, subfusiform, fusiform or ventricose thin-walled, colourless in KOH, no encrustations. *Pleurocystidia* 47–65 × 11–17 µm, abundant, subfusiform or fusiform, thin-walled, colourless, occasionally yellowish brown in KOH, no encrustations. *Pileipellis* a trichoderm about 190 µm thick, composed of interlaced hyphae, 6–13 µm diam, thin- to slightly thick-walled (up to 0.5 µm), colourless in KOH; terminal cells 34–65 × 8–13 µm, sometimes expanded to 19 µm wide, clavate to subcylindrical, with obtuse apex. *Pileus trama* composed of interlaced hyphae 5–15 µm diam, thin-walled, yellowish in KOH. *Stipitipellis* a trichoderm-like structure about 150 µm thick, composed of erect, slightly interlaced, filamentous hyphae, thin-walled, 4–9 µm diam, colourless in KOH; terminal cells 38–80 × 5–11 µm, clavate to subcylindrical. *Stipe trama* composed of longitudinally arranged, parallel hyphae 4–18 µm wide, cylindrical, thin-walled, light yellow in KOH. *Clamp connections* absent in all tissues.

**Habitat:** Solitary on the ground in mixed forests dominated by *Pinus yunnanensis*, *Pin. kesiya*, *Pin. armandii*, and fagaceous trees.

**Known distribution:** Southwestern China (Yunnan Province).

**Notes:** Morphologically, *Bol. rubidus* is similar to *Bol. ananiceps*, *Bol. emodensis*, *Bol. deceptivus*, *Bol. dissiliens*, *Bol. squamosus*, and *Bol. yunnanensis*. However, *Bol. ananiceps* has a pileus coloured with pink to pale red below the squamae, a yellow context, a stipe context changing brownish orange or pinkish brown when injured, basidiospores without cross-striations on the ridges, and a distribution in Australia (Singer 1955, Halling & Fechner 2011, Halling *et al.* 2015); *Bol. emodensis* has a yellow context, and longer basidiospores measuring 18.5–21.5 × 7.5–9 µm with ridges projecting 1–1.5 µm (see above); *Bol. deceptivus* has a yellow context, smaller basidiospores measuring 15.4–17.5 × 7–7.7 µm, hyphae in pileipellis wider (up to 17.5 µm), and a distribution in Australia associating with *Myrtaceae*, *Allocasuarina* (Halling *et al.* 2015); *Bol. dissiliens*, originally described from Singapore, has an absence of red pigmentation in pileus, a yellow pileal context, and smaller basidiospores measuring 14–16 × 5.5–7 µm (Corner 1972, Halling *et al.* 2015); *Bol. squamosus* has a pileus without reddish tinge, larger basidiospores measuring 17–21 × 9–11 µm with ridges projecting 1–1.5 µm, and it is associated with trees of *Pinaceae* (see below); *Bol. yunnanensis* has larger basidiospores measuring 18.5–22.5 × 9.5–11 µm with ridges projecting 1–1.5 µm (see below).

Phylogenetically, *Bol. rubidus* is closely related to *Bol. ananas* and *Bol. areolatus* (Fig. 2). However, the pileus of *Bol. ananas* is pink or red, then fades to pale fuscous tan, the stipe is never red, and a distribution in North/Central America (Smith & Thiers 1971, Zeng & Yang 2011, Halling *et al.* 2015). *Boletellus areolatus* has a pileus covered with more or less erect scales, basidiospores with ridges projecting 1–2 µm, and hyphae in pileipellis narrower (up to 8 µm) (see above).

***Boletellus sinochrysenoides*** N.K. Zeng, R. Xue & Kuan Zhao, *sp. nov.* MycoBank MB 840075. Figs 21J, K, 24C, 26C, 37.

**Etymology:** *sinochrysenoides* (Lat.), meaning the new species is similar to *Bol. chrysenoides* in morphology, but currently found from China.

**Diagnosis:** Differs from other species of *Boletellus* by a small, brown pileus, the hymenophore and context turning blue when injured, distinctly striate basidiospores with cross-striations on ridges, and a pileipellis with clavate terminal cells having acute apex and slightly inflated sub-terminal elements (up to 16 µm).

**Typus:** China, Jiangxi Province, Jiujiang City, Lushan Botanical Garden, elev. 50 m, K. Zhao, Zhao998 (**holotype** FHMU3264).

**Additional material examined:** China, Zhejiang Province: Hangzhou City, Tianmushan National Natural Reserve, elev. 700 m, K. Zhao, Zhao925 (FHMU3265).

**Description:** *Basidiomata* small-sized. *Pileus* 3.5–4 cm diam, subhemispherical to convex, then applanate, margin decurved; surface dry, brown (6D6) to dark brown (7F8), tomentose when young, sometimes cracking into appressed squamules; context 0.2–0.5 cm thick in the centre of pileus, yellow (4A5), turning blue (19C6) when injured. *Hymenophore* poroid, depressed around apex of stipe; pores about 0.5 mm diam, angular, yellow (4A5), turning blue (19C6) when injured; tubes 0.2–0.7 cm in length, yellowish (4A5), turning blue (19C6) when injured. *Stipe* 3–7 × 0.3–0.6 cm, central, subcylindrical, solid, flexuous; surface dry, concolourous with pileus, tomentose when young, then cracking into scabers; context yellow (4A5), turning blue (19C6) when injured; annulus absent; basal mycelium white (1A1). *Odour* indistinct.

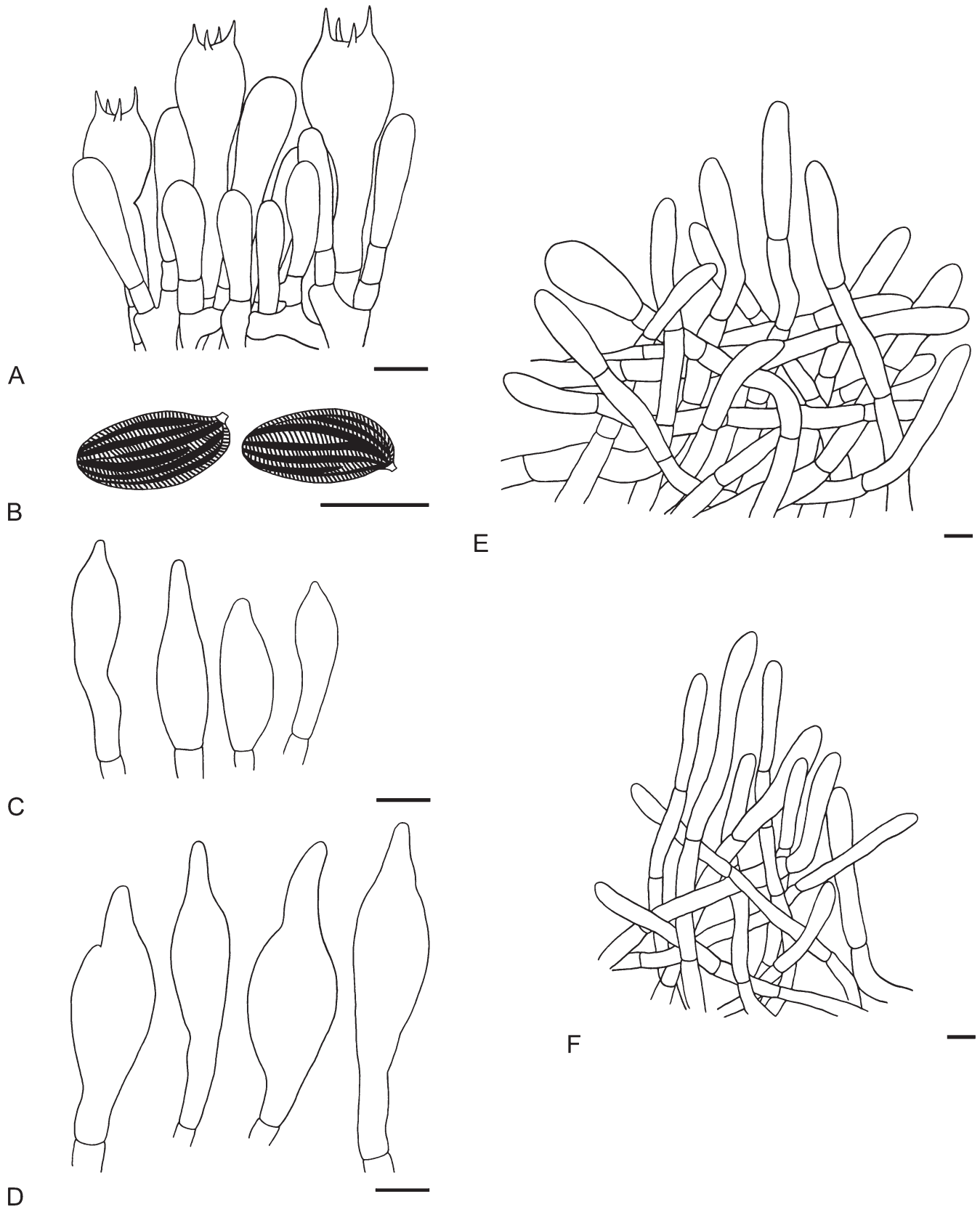
*Basidia* 28–37 × 11.5–15 µm, clavate, thin-walled, 4-spored, colourless in KOH; sterigmata 4–5 µm in length. *Basidiospores* [40/2/2] (11–)11.5–15.5(–16) × 6.5–8 µm,  $Q = (1.56–)1.57–2.07(–2.13)$ ,  $Q_m = 1.80 \pm 0.13$ , yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with longitudinal or oblique ridges, 6–10 ridges visible in lateral view; ridges continuous, projecting about 1 µm, with cross-striations on ridges. *Hymenophoral trama* boletoid, composed of hyphae 6–12 µm wide, thin- to slightly thick-walled (up to 0.5 µm), yellowish in KOH. *Cheilocystidia* 23–42 × 8.5–13.5 µm, not abundant, subfusiform or fusiform, thin-walled, colourless in KOH, no encrustations. *Pleurocystidia* 37–60 × 10–16.5 µm, not abundant, subfusiform or fusiform, thin-walled, colourless in KOH, no encrustations. *Pileipellis* a trichoderm about 160 µm thick, composed of more or less vertically arranged hyphae, up to 16 µm in width, thin-walled, yellow in KOH; terminal cells 25–60 × 6–11 µm, clavate to subcylindrical, with obtuse apex. *Pileus trama* composed of hyphae 5–15 µm diam, interwoven, subcylindrical, thin-walled, yellowish in KOH. *Stipitipellis* a trichoderm-like structure about 250 µm thick, composed of thin-walled, emergent hyphae, with subclavate, subfusiform or subcylindrical terminal cells (15–50 × 4–14 µm), yellowish to yellow in KOH. *Stipe trama* composed of longitudinally arranged, parallel hyphae 6–15 µm diam, cylindrical, thin-walled, light yellow in KOH. *Clamp connections* absent in all tissues.

**Habitat:** Solitary or gregarious on the ground in forests dominated by fagaceous trees.

**Known distribution:** Eastern China (Jiangxi and Zhejiang Provinces).

**Notes:** Although the genetic variation is low between Chinese collections and North American *Bol. chrysenoides* (Fig. 2), the new species "*Bol. sinochrysenoides*" was proposed due to the geographical isolation and morphological differences between Chinese specimens and *Bol. chrysenoides*, which is characterised by narrower basidiospores measuring 12–16 × 4.6–7.5 µm, and a pileipellis with cystidioid terminal cells and





**Fig. 36.** Microscopic features of *Boletellus rubidus* (holotype KUN-HKAS83069). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10 µm. Drawings by R. Xue.

inflated sub-terminal elements (12–20 µm broad and 15–30 µm long) (Smith & Thiers 1971). *Boletellus sinochrysenderoides* is also morphologically similar to *Bol. pseudochrysenderoides*, however, the latter has a dark rose red pileus, dull yellow basal mycelium, smaller basidiospores measuring 11–14 × 5.5–7 µm, and a distribution in North America (Smith & Thiers 1971).

Moreover, the brown pileus of *Bol. sinochrysenderoides* is reminiscent of *Bol. brunoflavus*, *Bol. fanjingensis*, *Bol. fujianensis*, *Bol. nordestinus*, *Bol. putuoensis*, *Bol. shoreae*, *Bol. sinapipes*, and *Bol. wenshanensis*. However, *Bol. brunoflavus* has smaller basidiospores measuring 10–12.5 × 4–5 µm with faint ridges, lacking cross-striations on ridges, and hyphae in pileipellis narrower (up to 12

$\mu\text{m}$ ) (see above); *Bol. fanjingensis* has a pileus tinged with reddish, hymenophore and context turning blue, then reddish when injured, basidiospores lacking cross-striations on ridges, and hyphae in pileipellis narrower (up to  $7\ \mu\text{m}$ ) (see above); *Bol. fujianensis* has larger basidiospores measuring  $19\text{--}23.5 \times 10.5\text{--}12\ \mu\text{m}$ , and hyphae in pileipellis narrower (up to  $9\ \mu\text{m}$ ) (see above); *Bol. nordestinus* has non-cyanescent hymenophore and context, smaller basidiospores measuring  $8\text{--}10 \times 6\text{--}7\ \mu\text{m}$ , and a distribution in South America (Magnago *et al.* 2019); *Bol. putuoensis* has smaller basidiospores measuring  $9\text{--}12 \times 6\text{--}7.5\ \mu\text{m}$  without cross-striations on ridges (see above); *Bol. shoreae* has smaller basidiospores measuring  $8\text{--}11 \times 5.3\text{--}7.6\ \mu\text{m}$ , and it is associated with trees of *Dipterocarpaceae* (Parihar *et al.* 2018), *Bol. sinapipes* has a mustard brown-coloured tomentum at the base of the stipe, basidiospores without cross-striations on ridges, and a distribution in Australia (Halling *et al.* 2015); *Bol. wenshanensis* has a stipe covered with golden yellow, orange to brownish yellow punctate squamules, and a pileipellis composed of filamentous hyphae (Zhang & Wu 2022).

***Boletellus squamosus*** Zang, Acta Bot. Yunnan. 7: 392. 1985. MycoBank MB 104056. Figs 22A–C, 24D, E, 26D, E, 38–39.

**Description:** *Basidiomata* medium-sized. *Pileus* 5–7 cm diam, subhemispherical to convex, then applanate, margin at first extended into a false veil and covering the pores, then splitting radially, appendiculate with false veil remnants; surface dry, densely covered with brown to brownish pink, hairy, large, appressed squamules; context about 0.7 cm thick in the centre of the pileus, yellow, turning blue strongly and quickly when injured. *Hymenophore* poroid, depressed around apex of stipe, pores 0.5–1 mm diam, angular, yellow, turning blue strongly and quickly when injured; tubes about 1.5 cm in length, yellowish, turning blue strongly and quickly when injured. *Stipe* 5–8  $\times$  0.8–1 cm, central, subcylindrical, solid, flexuous; surface dry, fibrous, concolourous with pileus; context yellow, turning blue strongly and quickly when injured; annulus absent; basal mycelium white. *Odour* indistinct.

*Basidia* 34–43  $\times$  13–18  $\mu\text{m}$ , clavate, thin-walled, 4-spored, colourless to yellowish in KOH; sterigmata 5–7  $\mu\text{m}$  in length. *Basidiospores* [40/2/1] (16.5–)17–21(–22)  $\times$  9–11  $\mu\text{m}$ ,  $Q = (1.55\text{--})1.71\text{--}2.11(2.17)$ ,  $Q_m = 1.92 \pm 0.13$ , yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with 6–9 longitudinal or oblique ridges visible in lateral view; ridges continuous or forked, rarely not continuous, projecting 1–1.5  $\mu\text{m}$ , with cross-striations on the ridges observed under the light microscope. *Hymenophoral trama* boletoid, composed of hyphae 5–15  $\mu\text{m}$  wide, yellowish in KOH. *Cheilocystidia* 41–65  $\times$  10–16  $\mu\text{m}$ , abundant, subfusiform or fusiform, thin-walled, colourless to yellow in KOH, no encrustations. *Pleurocystidia* 54–80  $\times$  10–17  $\mu\text{m}$ , abundant, subfusiform or fusiform, thin-walled, colourless to yellow in KOH, no encrustations. *Pileipellis* a trichoderm about 300  $\mu\text{m}$  thick, composed of interlaced, occasionally branched filamentous hyphae 6–10  $\mu\text{m}$  diam, thin-walled, yellow in KOH; terminal cells 25–70  $\times$  6–14  $\mu\text{m}$ , clavate to subcylindrical with obtuse apex. *Pileus trama* composed of hyphae 9–18  $\mu\text{m}$  diam, interlaced, subcylindrical, thin-walled, colourless in KOH. *Stipitipellis* a trichoderm-like structure about 150  $\mu\text{m}$  thick, composed of yellowish in KOH, thin-walled filamentous hyphae, with subclavate or subcylindrical terminal cells (21–72  $\times$  5–9  $\mu\text{m}$ ), and with clavate, 4-spored basidia. *Stipe trama* composed of longitudinally arranged, parallel hyphae 4–9  $\mu\text{m}$  diam, cylindrical, thin-walled, colourless in KOH. *Clamp connections* absent in all tissues.

**Habitat:** Gregarious on the ground in forests dominated by *Pinus latteri* or *Pin. yunnanensis*.

**Known distribution:** Southern (Hainan Province) and southwestern China (Yunnan Province); Thailand (Fig. 2).

**Materials examined:** **China**, Hainan Province, Bawangling of Hainan Tropical Rainforest National Park, 23 May 2019, N.K. Zeng, Zeng4051 (FHMU3266); Yunnan Province, Nujiang of the Lisu Autonomous Prefecture, Zhiziluo Village (previously called “Bijiang County”), Gaoligongshan National Nature Reserve, elev. 2 612 m, 27 Jul. 1978, M. Zang, Zang4012 (**holotype** KUN-HKAS4112); Baoshan City, on the way from Baoshan to Changning, Wojiaodi Village, elev. 1 780 m, 24 Jul. 2009, Y.C. Li, Li1789 (KUN-HKAS59536).

**Notes:** *Boletellus squamosus* was first described from Yunnan Province of southwestern China in 1985; however, the information on the morphological structures of the species was scanty (Zang 1985). New collections and the holotype of the species were examined carefully in the present study, the characteristics of the taxon were updated. It is well characterised by a pileus densely covered with brown to brownish pink, hairy, large, appressed squamules, a yellow context in both pileus and stipe that is strongly and rapidly cyanescent in both when injured, large, longitudinally striate basidiospores with fine cross-striations on ridges, a pileipellis composed of filamentous hyphae, and it is associated with pine trees. *Boletellus squamosus* is easily confused with *Bol. areolatus* and *Bol. yunnanensis* in China. However, both *Bol. areolatus* and *Bol. yunnanensis* are associated with fagaceous trees (see above). Moreover, *Bol. areolatus* has a red pileus and a white context; *Bol. yunnanensis* has a pileipellis composed of slightly inflated hyphae (see above).

*Boletellus squamosus* is also morphologically similar to *Bol. ananas*, *Bol. ananiceps*, *Bol. deceptivus*, and *Bol. dissiliens*. However, *Bol. ananas* has a pileus pink or red, then fades to pale fuscous tan, a stipe never red, narrower basidiospores measuring 16–20  $\times$  7.5–9.5  $\mu\text{m}$ , and a distribution in North/Central America (Smith & Thiers 1971, Zeng & Yang 2011, Halling *et al.* 2015); *Bol. ananiceps* has a pileus coloured with pink to pale red below the squamae, a stipe context changing brownish orange or pinkish brown when injured, basidiospores without cross-striations on ridges, and a distribution in Australia (Singer 1955, Halling & Fechner 2011, Halling *et al.* 2015); *Bol. deceptivus* has smaller basidiospores measuring 15.4–17.5  $\times$  7–7.7  $\mu\text{m}$ , hyphae in pileipellis wider (up to 17.5  $\mu\text{m}$ ), and a distribution in Australia associating with *Myrtaceae*, *Allocasuarina* (Halling *et al.* 2015); *Bol. dissiliens*, originally described from Singapore, has smaller basidiospores measuring 14–16  $\times$  5.5–7  $\mu\text{m}$  (Corner 1972, Halling *et al.* 2015).

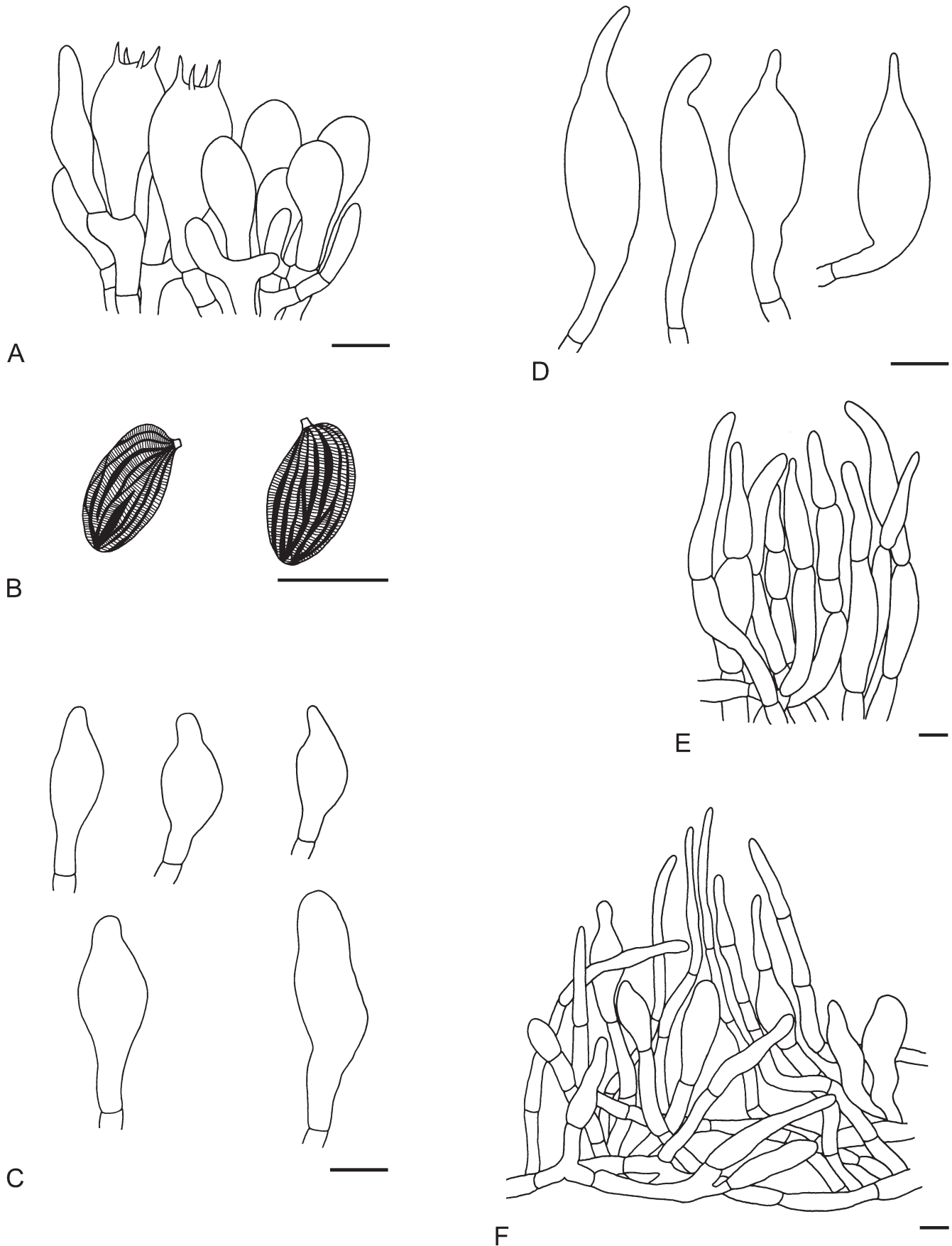
Phylogenetically, *Bol. squamosus* is closely related to *Bol. emodensis* (Fig. 2). However, the latter has a reddish brown, purplish red to red pileus, and narrower basidiospores measuring 18.5–21.5  $\times$  7.5–9  $\mu\text{m}$  (see above).

***Boletellus subglobosus*** N.K. Zeng, R. Xue, S. Jiang & Zhi Q. Liang, **sp. nov.** MycoBank MB 840071. Figs 22D, E, 24F, 26F, 40.

**Etymology:** *subglobosus* (Lat.), refers to the subglobose hyphae in pileipellis.

**Diagnosis:** Differs from other species of *Boletellus* by a small to medium-sized basidioma, a pileus with reddish to dark red scales, broad pores, hymenophore and context unchanging in colour

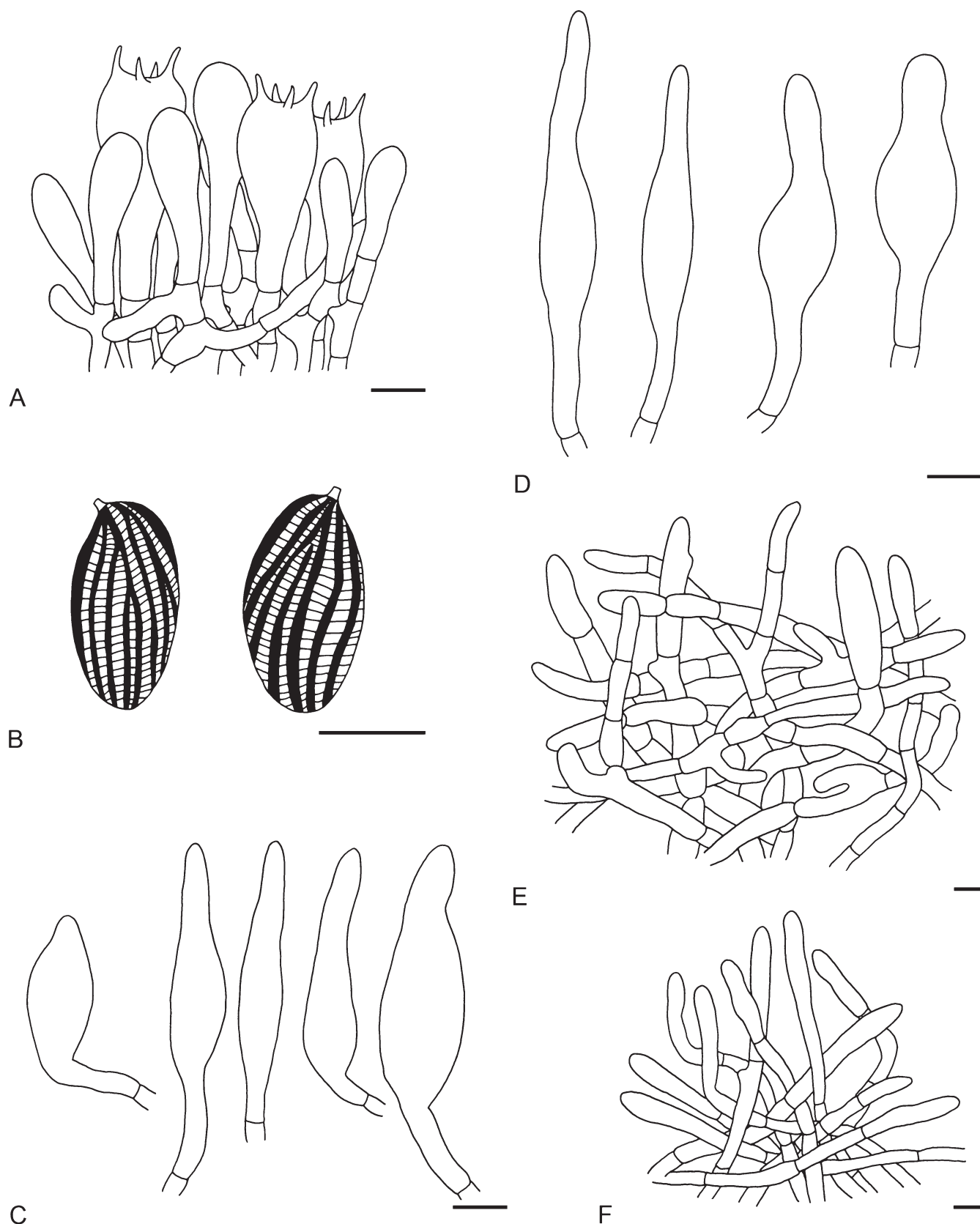




**Fig. 37.** Microscopic features of *Boletellus sinochrysenteroides* (holotype FHMU3264). **A.** Basidia and pleurocystidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10 µm. Drawings by R. Xue.

when injured, shallowly longitudinal striate basidiospores without cross-striations on ridges, and a pileipellis composed of chains of subglobose, globose to subcylindrical cells.

*Typus:* **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 750 m, 27 Jul. 2017, S. Jiang, Jiang100 (**holotype** FHMU3256).

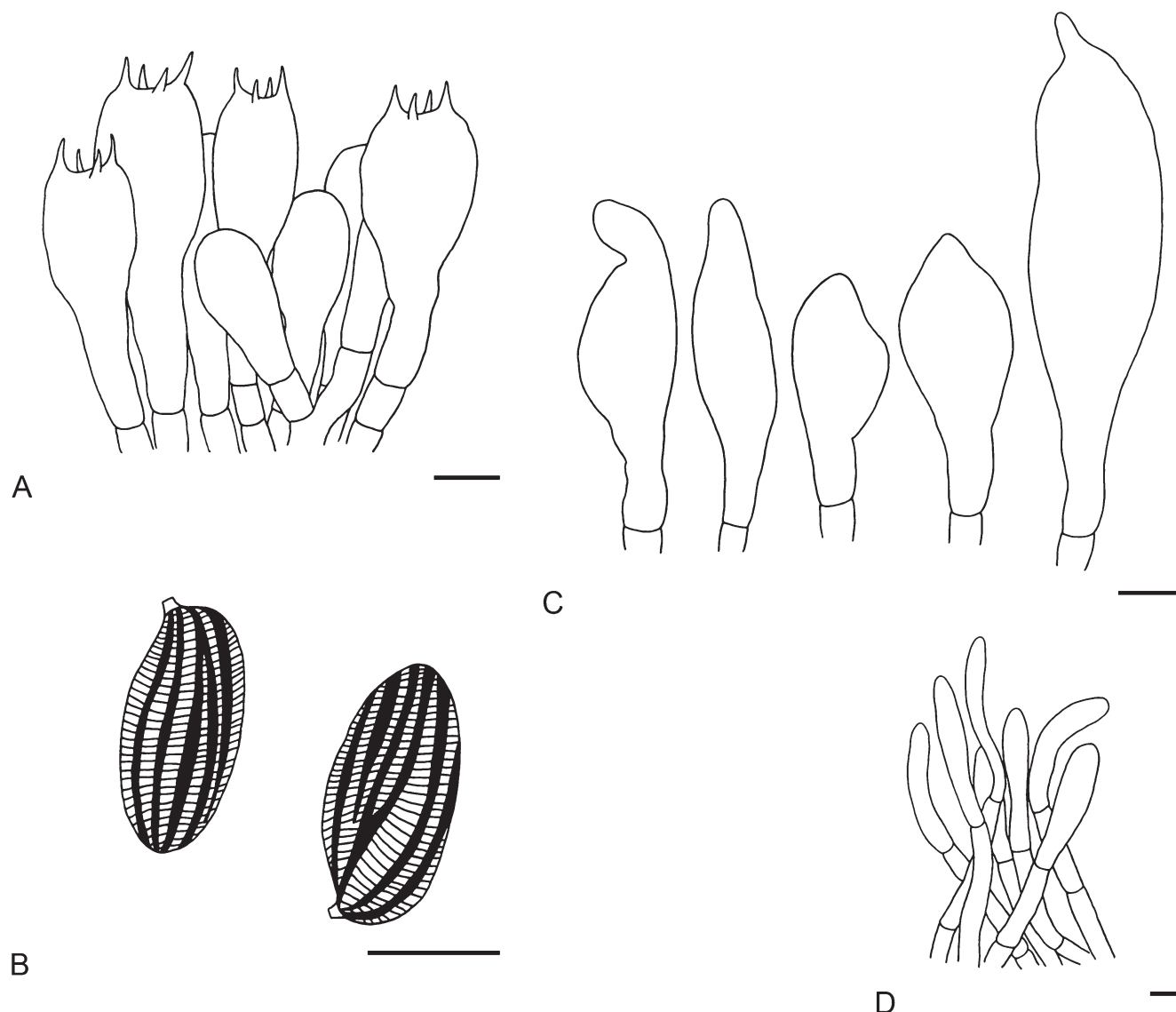


**Fig. 38.** Microscopic features of *Boletellus squamosus* (FHMU3266). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10 µm. Drawings by R. Xue.

*Additional materials examined:* **China**, Hainan Province, Qiongzong County, Yinggeling National Nature Reserve, elev. 750 m, 27 Jul. 2017, S. Jiang, Jiang98, 99 (FHMU3258, 3257); same location, 3 Aug. 2015, N.K. Zeng, Zeng2506 (FHMU3259).

*Description:* *Basidiomata* small to medium-sized. *Pileus* 1.8–7 cm diam, subhemispherical to applanate, margin decurved; surface dry, densely covered with reddish (10A8) to dark red (11E8) scales; context 0.1–0.2 cm thick in the centre of the pileus, yellow (4A5), unchanging in colour when injured. *Hymenophore* poroid,





**Fig. 39.** Microscopic features of *Boletellus squamosus* (holotype KUN-HKAS4112). **A.** Basidia. **B.** Basidiospores. **C.** Cheilo- and pleurocystidia. **D.** Pileipellis. Scale bars = 10 µm. Drawings by R. Xue.

depressed around apex of stipe; pores angular, 0.1–0.2 cm diam, yellow (4A5), unchanging in colour when injured; tubes 0.4–0.5 cm in length, pale yellow (2B7), unchanging in colour when injured. *Stipe* 2.5–2.8 × 0.2–0.4 cm, central, subcylindrical, solid; surface dry, densely covered with pink (7A3) to red (10A8) scales; context yellow (4A5), unchanging in colour when injured; annulus absent; basal mycelium white (1A1). *Odour* indistinct.

*Basidia* 28–50 × 10–15 µm, clavate, thin- to slightly thick-walled (up to 1 µm), 4-spored, yellowish to yellowish brown in KOH; sterigmata 4–6 µm in length. *Basidiospores* [60/3/3] 15–19 × (6–)6.5–8(–8.5) µm,  $Q = (2-)2.2-2.85(-3.17)$ ,  $Q_m = 2.49 \pm 0.24$ , yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with shallowly longitudinal ridges, 10–15 ridges visible in lateral view; ridges continuous or forked, united at the apex. *Hymenophoral trama* boletoid, composed of hyphae 4–12 µm wide, colourless to light yellow in KOH. *Cheilocystidia* 27–54 × 8–13 µm, abundant, subclavate or subfusiform, thin-walled, colourless to yellowish in KOH, no encrustations. *Pleurocystidia* 39–81 × 8–13 µm, abundant, subclavate, subfusiform or fusiform, thin- to slightly thick-walled (up to 1 µm), colourless to yellowish in KOH, no encrustations. *Pileipellis* a trichoderm about 197 µm thick, composed of chains of subglobose, pyriform to broadly subcylindrical cells up to 20

µm in width arising from filamentous hyphae, thin- to slightly thick-walled (up to 1 µm), yellow to yellowish brown in KOH; terminal cells 25–62 × 9–17 µm, subglobose, pyriform to subcylindrical, with obtuse apex. *Pileus trama* composed of hyphae 7–11 µm diam, thin- to slightly thick-walled (up to 1 µm), yellowish in KOH. *Stipitipellis* a trichoderm-like structure about 150 µm thick, composed of yellow to yellowish brown in KOH, thin-walled emergent hyphae with subclavate, subfusiform or subcylindrical terminal cells (22–49 × 6.5–14 µm), and with clavate, 4-spored basidia. *Stipe trama* composed of longitudinally arranged, parallel hyphae 3–13 µm diam, cylindrical, thin-walled, colourless in KOH. *Clamp connections* absent in all tissues.

*Habitat:* Solitary on the ground in forests of dominated by fagaceous trees.

*Known distribution:* Southern China (Hainan Province).

*Notes:* In China, *Bol. subglobosus* was misidentified as *Bol. obscurecoccineus*, however, the Indonesian species has a tomentose pileus, wider basidiospores measuring 16–20.5 × 7.5–8.5 µm, and a pileipellis without subglobose or globose cells (Zeng

& Yang 2011). Based on morphological features and geographical distributions provided by Wu *et al.* (2016), two collections labeled as *Bol. obscurecoccineus* from subtropical China including Yunnan Province were actually *Bol. puniceus*. *Boletellus subglobosus* is highly similar to *Bol. puniceus*. However, *Bol. puniceus* has a slender basidioma, a pileipellis composed of chains of subcylindrical, few subglobose to globose cells, and a distribution in subtropical China (Wang & Liu 2002, Wu *et al.* 2016). Phylogenetically, *Bol. subglobosus* is also somewhat distant from *Bol. puniceus* (Fig. 2).

***Boletellus violaceus*** M. Zang & H.C. Tan, Acta Bot. Yunnan. 7: 393. 1985. MycoBank MB104057. Figs 22F, G, 24G, 26G, 41.

Macroscopic descriptions are from the protologue (Zang 1985); microscopic descriptions are from our examinations.

*Description*: “Pileus 4–6 cm latus, convexus demum leviter complanatus, siccus, subtomentosus, hirsutus vel squamulosus, rimosoareolus vel cutifRACTUS, purpureus vel violaceus. Contextus 0.5–1.6 cm crassus, albus laete luteus, immutabilis. Tubuli 3–5 mm longi, adnexi vel sinuato-adnexi. Stipes 5–8 cm longus, 5–10 mm crassus, bulbosus basim versus incrassatus, laevigatus et striatus, non-reticulatus, apice purpureus, basim versus purpureo-brunneus.”

Basidia 32–45 × 13–18 µm, clavate, thin-walled, 4-spored, yellow in KOH; sterigmata 3–6 µm in length. Basidiospores [20/1/1] 20–24 × 10–11 µm, Q = 1.9–2.4, Qm = 2.05 ± 0.12, ellipsoid, with 5–8 continuous longitudinal or forked ridges, projecting 0.8–1.8 µm, with cross-striations on the ridges observed under the light microscope, light yellow to yellowish brown in KOH. Hymenophoral trama boletoid, composed of hyphae 5–10 µm wide, light yellow to yellow in KOH. Cheilo- and pleurocystidia 28–50 × 9–15 µm, subfusiform or ventricose, thin-walled, yellow in KOH, no encrustations. Pileipellis composed of erect, slightly interwoven, filamentous hyphae, 5–13 µm diam, thin- to slightly thick-walled (up to 0.5 µm), light yellow to yellowish brown in KOH; terminal cells 15–42 × 8–15 µm, subcylindrical to subclavate. Pileus trama composed of interwoven hyphae 4–15 µm diam, light yellow to yellow in KOH.

*Habitat*: Solitary on the ground in forests dominated by broad-leaved forests.

*Known distribution*: Southeastern China (Fujian Province).

*Material examined*: China, Fujian Province, Nanjing County, 1 Jul. 1975, H.C. Tan, Tan2360 (**holotype** KUN-HKAS10249).

*Notes*: *Boletellus violaceus*, first described from Fujian Province of southeastern China, is a poorly known species (Zang 1985). In the present study, the holotype of the species was re-examined, characterised by purple pileus and stipe, non-cyanescent hymenophore and context, large, longitudinally ridged basidiospores with fine cross-striations on ridges, a pileipellis composed of filamentous to slightly inflated hyphae. *Boletellus violaceus* is similar to *Bol. fujianensis* and *Bol. nordestinus* with non-cyanescent hymenophore and context. However, *Bol. fujianensis* has a pileus covered with brown scales, and hyphae in pileipellis narrower (up to 9 µm) (see above); *Bol. nordestinus* has a brown pileus, shorter basidiospores measuring 8–10 × 6–7 µm, and a distribution in South America (Magnago *et al.* 2019).

***Boletellus wenshanensis*** G. Wu & Xin Zhang, Phytotaxa 547: 182. 2022. MycoBank MB 842992.

*Known distribution*: Southwestern China (Yunnan Province) (Zhang & Wu 2022).

*Holotype*: KUN-HKAS122938 (China, Yunnan Province).

*Notes*: *Boletellus wenshanensis* was originally described from Yunnan Province, southwestern China (Zhang & Wu 2022). Illustrations and a full description of the species have been provided by Zhang & Wu (2022).

***Boletellus yunnanensis*** M. Zang, Acta Bot. Yunnan. 7: 391. 1985. MycoBank MB 104059. Figs 22H, I, 24H, 26H, 42.

Macroscopic descriptions are from the protologue (Zang 1985); microscopic descriptions are from our examinations.

*Description*: “Pileus 8–12 cm latus, planus, siccus, subtomentosus demum cutifRACTUS, subcervinus vel fuscus. Margine appendiculato. Contextus 1–3 cm crassus, fuscus, spongioso-cavus vel vermiculocavus, brunneus, haud cyanescentibus. Tubuli 1–2 cm longi, liberati, glandaceus et umbrinus. Pori elliptio-angulares vel irregulares, 4–5 per cm. Stipes 7–9 cm longus, 1–2 cm crassus, laete cylindricus et basim versus attenuatus, laevigatus, subcervinus.”

Basidia 38–51 × 11–17 µm, clavate, thin-walled, 4-spored, yellowish in KOH; sterigmata 4–7 µm in length. Basidiospores [20/1/1] 18.5–22.5 × 9.5–11 µm, Q = 1.81–2.21, Qm = 1.99 ± 0.11, yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with 5–8 longitudinal or oblique ridges visible in lateral view; ridges continuous or forked, projecting 1–1.5 µm, with cross-striations on the ridges observed under the light microscope, united at the apex. Hymenophoral trama boletoid, composed of hyphae 7–15 µm wide, yellow in KOH. Cystidia 39–78 × 10–20 µm, subfusiform or subfusiform, thin-walled, yellowish in KOH, no encrustations. Pileipellis a trichoderm composed of more or less vertically arranged hyphae, 7–16 µm diam, thin- to slightly thick-walled (up to 0.5 µm), yellow in KOH; terminal cells 15–62 × 8–15 µm, subglobose, subcylindrical to subclavate, with obtuse apex. Pileus trama composed of interlaced hyphae 9–17 µm diam, yellowish to yellow in KOH.

*Habitat*: Solitary on the ground in forests dominated by fagaceous trees.

*Known distribution*: Southwestern China (Yunnan Province).

*Material examined*: China, Yunnan Province, Mang City (previously called “Luxi County”), Santai Mountain, elev. 1 370 m, 1 Jul. 1977, X.J. Li, Li41 (**holotype** KUN-HKAS2871).

*Notes*: *Boletellus yunnanensis*, first described from Yunnan Province of southwestern China, is a poorly known species (Zang 1985). In the present study, the holotype of the species was re-examined, characterised by a large pileus, a context turning blue when injured, longitudinally ridged basidiospores with fine cross-striations on ridges, a pileipellis composed of slightly inflated hyphae, and it is associated with fagaceous trees.

In China, *Bol. yunnanensis* is easily confused with *Bol. areolatus*, *Bol. emodensis*, *Bol. rubidus*, and *Bol. squamosus*. However, both *Bol. areolatus* and *Bol. emodensis* have narrower hyphae



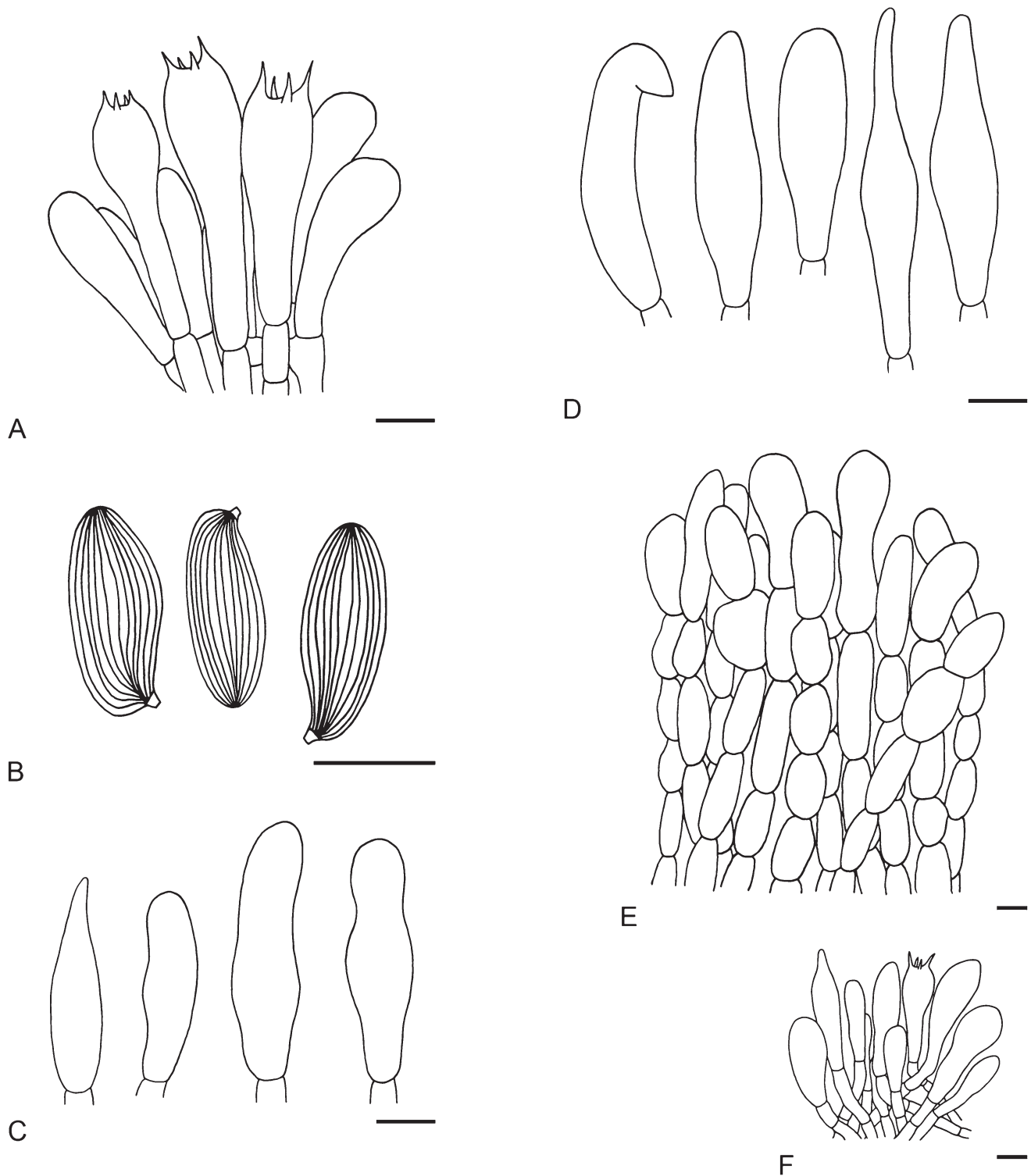


Fig. 40. Microscopic features of *Boletellus subglobosus* (holotype FHMU3256). A. Basidia. B. Basidiospores. C. Cheilocystidia. D. Pleurocystidia. E. Pileipellis. F. Stipitipellis. Scale bars = 10 µm. Drawings by R. Xue.

in pileipellis (see above). Moreover, *Bol. areolatus* has smaller basidiospores measuring  $15\text{--}21 \times 7\text{--}10\text{ }\mu\text{m}$ ; *Bol. emodensis* has narrower basidiospores measuring  $18.5\text{--}21.5 \times 7.5\text{--}9$  (see above). The morphological differences of *Bol. yunnanensis*, *Bol. rubidus*, and *Bol. squamosus* have been discussed under *Bol. rubidus* and *Bol. squamosus*, respectively (see above).

*Boletellus yunnanensis* is also morphologically similar to *Bol. ananas*, *Bol. ananiceps*, *Bol. deceptivus*, and *Bol. dissiliens*. However, *Bol. ananas*, originally described from North America, has a pileus pink or red, then pale fuscous tan, with coarse

squama, smaller basidiospores measuring  $16\text{--}20 \times 7.5\text{--}9.5\text{ }\mu\text{m}$ , and a stipe without red pigmentation (Smith & Thiers 1971, Zeng & Yang 2011); *Bol. ananiceps*, originally described from Australia, has basidiospores without cross-striations on ridges (Halling *et al.* 2015). Australian *Bol. deceptivus* has smaller basidiospores measuring  $15.4\text{--}17.5 \times 7\text{--}7.7\text{ }\mu\text{m}$  (Halling *et al.* 2015); Singaporean *Bol. dissiliens* has an absence of red pigmentation in pileus, and smaller basidiospores measuring  $14\text{--}16 \times 5.5\text{--}7\text{ }\mu\text{m}$  (Corner 1972, Halling *et al.* 2015).

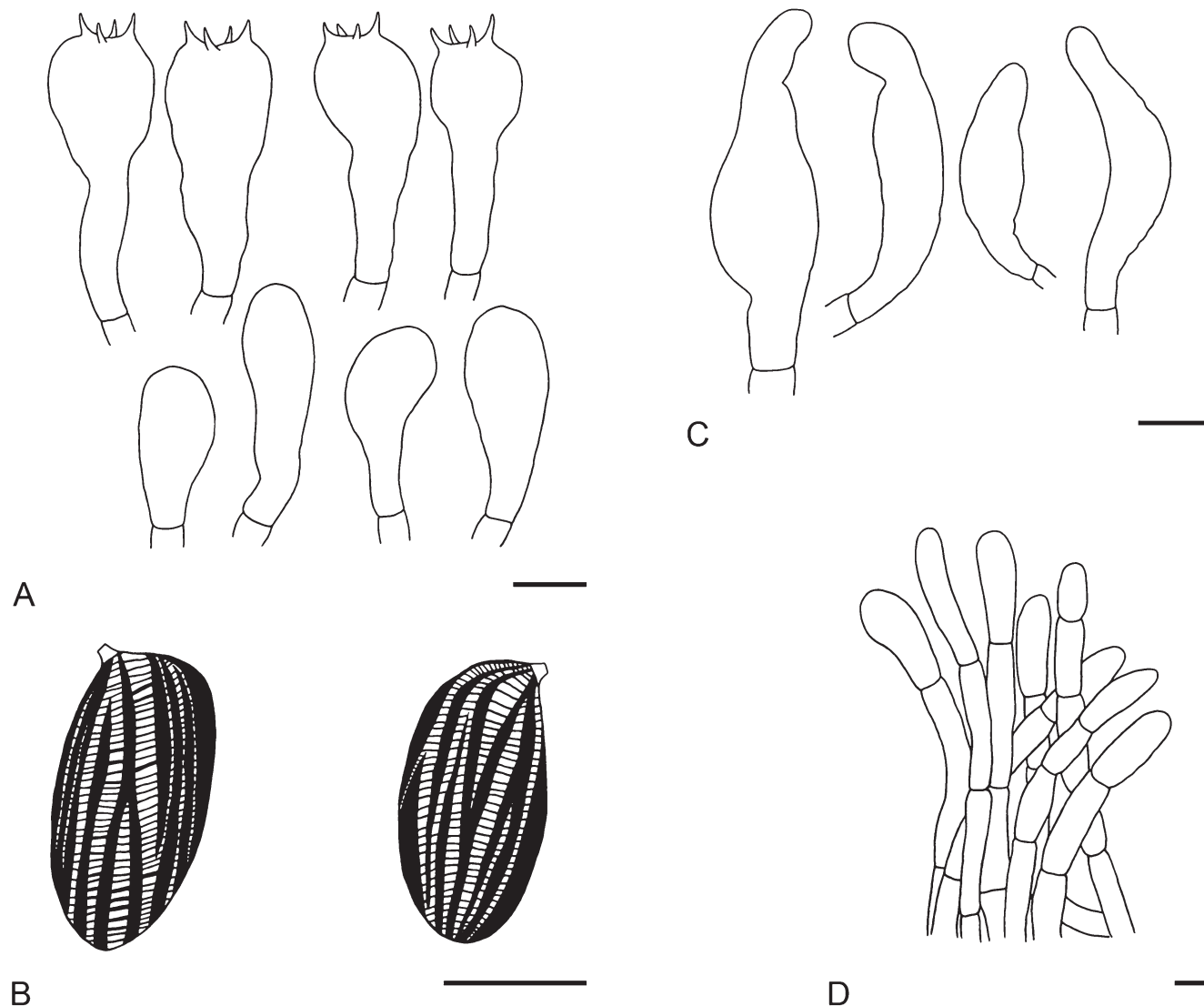


Fig. 41. Microscopic features of *Boletellus violaceus* (holotype KUN-HKAS10249). A. Basidia. B. Basidiospores. C. Cheilo- and pleurocystidia. D. Pileipellis. Scale bars = 10  $\mu$ m. Drawings by R. Xue.

***Boletellus zenghuoxingii*** N.K. Zeng, R. Xue, S. Jiang & Zhi Q. Liang, *sp. nov.* MycoBank MB 840077. Figs 22J, K, 24I, 26I, 43.

**Etymology:** *zenghuoxingii* (Lat.) is named after N.K. Zeng's father Huo-Xing Zeng, who was not only an expert in cultivating *Lentinula edodes* and *Auricularia cornea*, but also encouraged N.K. Zeng's interest in the taxonomy of fungi.

**Diagnosis:** Differs from other species of *Boletellus* by a medium-sized basidioma, a pileus with erect, cone shape scales, a stipe with pallid or pale cream colour at lower part, and relatively large basidiospores with cross-striations on the ridges, and a pileipellis composed of slightly inflated hyphae.

**Typus:** China, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 750 m, 4 Aug. 2015, N.K. Zeng, Zeng2553 (holotype FHMU3251).

**Additional material examined:** China, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 25 May 2017, N.K. Zeng, Zeng3018 (FHMU1979).

**Description:** *Basidiomata* medium-sized. *Pileus* 5–7 cm diam, subhemispherical to convex, margin at first extending into a false

veil and covering the pores, then splitting radially, appendiculate with false veil remnants; surface dry, covered with deep red (11C8), greyish red (11B6), pinkish red (7A3) to brownish red (10C6), more or less erect, cone shape scales; context about 0.7 cm thick in the centre of the pileus, yellow (4A5), turning blue (19C6) quickly when injured. *Hymenophore* poroid, depressed around apex of stipe; pores angular, yellow (4A5), turning blue (19C6) quickly when injured; tubes about 1.2 cm in length, yellowish (1A4), turning blue (19C6) quickly when injured. *Stipe* 5–8.5  $\times$  0.8–1 cm, central, subcylindrical, solid; surface dry, purplish red (14C8) to brown (6E8), with longitudinal ridges; context pale yellow (2B7), unchanging in colour when injured; annulus absent; basal mycelium white (1A1). *Odour* indistinct.

*Basidia* 30–59  $\times$  11–16  $\mu$ m, clavate, thin-walled, 4-spored, colourless to yellowish brown in KOH; sterigmata 4–6  $\mu$ m in length. *Basidiospores* [40/2/2] (17.5–)18–22  $\times$  (7.5–)8–9.5(–10)  $\mu$ m, Q = 2–2.44(–2.73), Qm = 2.3  $\pm$  0.17, yellowish to yellowish brown in KOH, ellipsoid to subfusiform, with longitudinal or oblique ridges, united at the apex, 7–12 ridges visible in lateral view; ridges continuous or forked, projecting 1–2  $\mu$ m, with cross-striations on the ridges observed under the light microscope. *Hymenophoral trama* boletoid, composed of hyphae 4–16  $\mu$ m wide, yellowish in KOH. *Cheilocystidia* 40–61  $\times$  13–19.5  $\mu$ m, not abundant, subfusiform



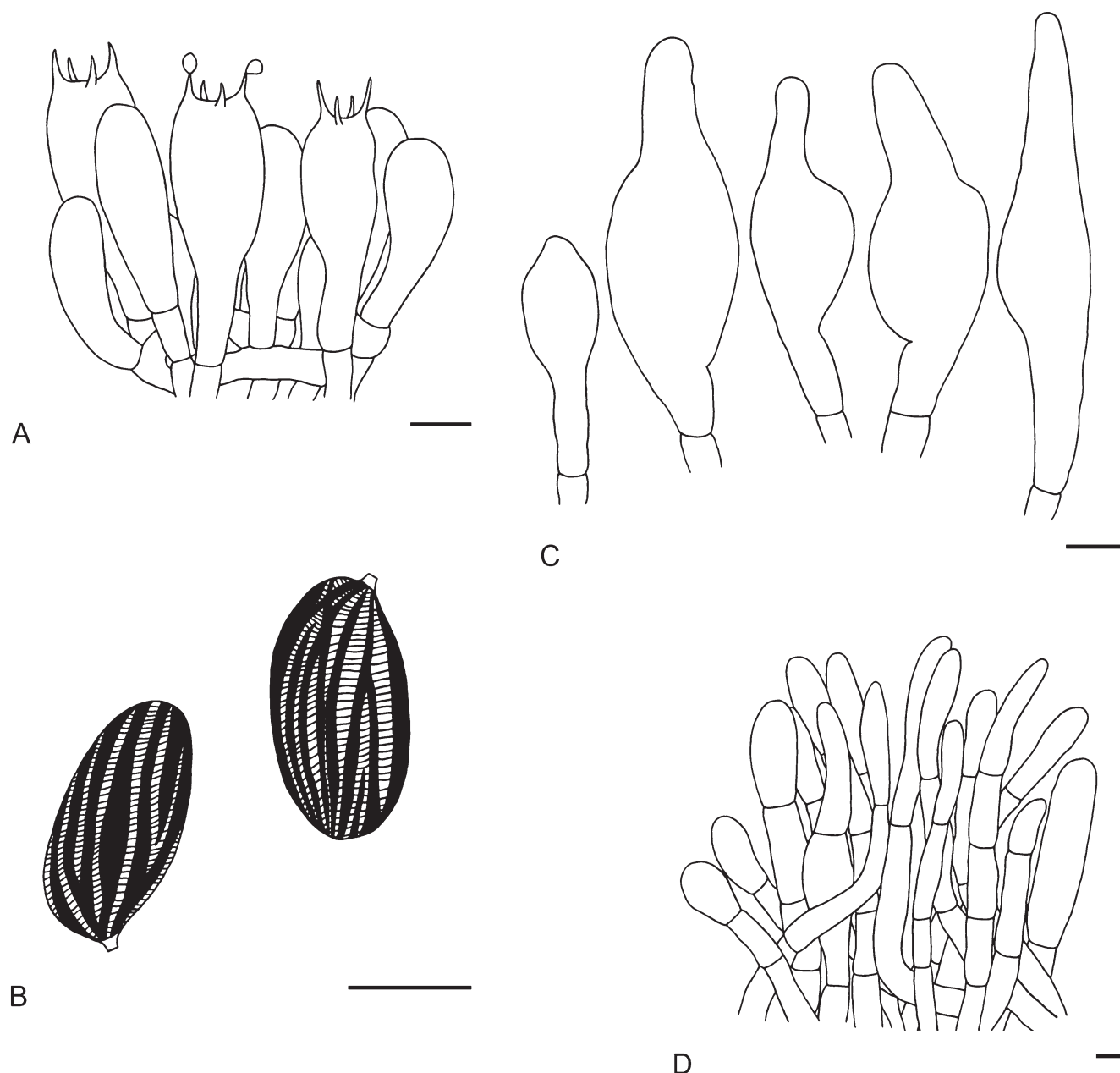


Fig. 42. Microscopic features of *Boletellus yunnanensis* (holotype KUN-HKAS2871). A. Basidia. B. Basidiospores. C. Cheilo- and pleurocystidia. D. Pileipellis. Scale bars = 10 µm. Drawings by R. Xue.

or fusiform, thin-walled, yellowish in KOH, no encrustations. *Pleurocystidia* 83–103 × 11–17 µm, not abundant, subfusiform or fusiform, thin- to slightly thick-walled (up to 0.5 µm), colourless in KOH, no encrustations. *Pileipellis* a trichoderm about 300 µm thick, composed of slightly interlaced hyphae, 7–12 µm diam, thin-walled, yellowish brown in KOH; terminal cells 22.5–42 × 6–13 µm, clavate to subcylindrical, with obtuse apex. *Pileus trama* composed of interlaced hyphae 6–9 µm diam, thin- to slightly thick-walled (up to 0.5 µm), yellowish in KOH. *Stipitipellis* a trichoderm-like structure about 170 µm thick, composed of more or less vertically arranged hyphae, thin-walled, 6–10 µm diam, yellowish brown in KOH; terminal cells 32–53 × 7–11 µm, clavate to subcylindrical, with obtuse apex. *Stipe trama* composed of longitudinally arranged, parallel hyphae 5–15 µm wide, cylindrical, thin-walled, light yellow in KOH. *Clamp connections* absent in all tissues.

*Habitat*: Solitary on the ground in forests dominated by fagaceous trees.

*Known distribution*: Southern China (Hainan Province).

*Notes*: *Boletellus zenghuoxingii* is easily confused with *Bol. areolatus*, *Bol. dissiliens*, *Bol. emodensis*, *Bol. rubidus*, *Bol. squamosus*, and *Bol. yunnanensis* in Asia. However, *Bol. areolatus* has a white context, shorter pleurocystidia, and a pileipellis composed of filamentous hyphae (see above); *Bol. dissiliens* has an absence of red pigmentation in pileus, and smaller basidiospores measuring 14–16 × 5.5–7 µm (Corner 1972, Halling *et al.* 2015); *Bol. emodensis* has a pileus with large, appressed scales, shorter pleurocystidia, and a pileipellis composed of filamentous hyphae; *Bol. rubidus* has a pileus with hairy, appressed squamules, shorter basidiospores measuring 15–19.5 × 7–9 µm, and a pileipellis composed of filamentous hyphae; *Bol. squamosus* has a pileus with large, appressed scales, wider basidiospores measuring 17–21 × 9–11 µm, shorter pleurocystidia, a pileipellis composed of filamentous hyphae, and it is associated with pine trees; *Bol. yunnanensis* has wider

basidiospores measuring  $18.5\text{--}22.5 \times 9.5\text{--}11\ \mu\text{m}$ , and shorter cystidia (see above).

Moreover, *Bol. zenghuoxingii* is also morphologically similar to some other out-Asian species, such as *Bol. ananas*, *Bol. ananiceps*, and *Bol. deceptivus*. However, *Bol. ananas* has a pileus pink or red, then pale fuscous tan, and a stipe without red pigmentation (Smith & Thiers 1971, Zeng & Yang 2011); *Bol. ananiceps* has

basidiospores without cross-striations on ridges (Halling *et al.* 2015); *Bol. deceptivus* has smaller basidiospores measuring  $15.4\text{--}17.5 \times 7\text{--}7.7\ \mu\text{m}$ , shorter cheilocystidia measuring  $30\text{--}40\ \mu\text{m}$ , and a distribution in Australia (Halling *et al.* 2015). Phylogenetically, species closely related to *Bol. zenghuoxingii* was not detected from our current data (Fig. 2).

## Key to accepted species of *Boletellus* in China

- 1a. Margin of pileus at first extended into a false veil and covering the pores, then splitting radially, appendiculate with false veil remnants ..... 2
- 1b. Margin of pileus without a false veil or false veil remnants ..... 7
- 2a. Pileus covered with erect, conical scales ..... *Bol. zenghuoxingii*
- 2b. Pileus covered with appressed scales ..... 3
- 3a. A pileipellis composed of somewhat inflated hyphae ..... *Bol. yunnanensis*
- 3b. A pileipellis composed of mostly filamentous hyphae ..... 4
- 4a. Context white ..... 5
- 4b. Context yellow ..... 6
- 5a. Basidiospores ridges projecting  $1\text{--}2\ \mu\text{m}$ , terminal cells of hyphae in pileipellis  $22\text{--}80 \times 5.5\text{--}11\ \mu\text{m}$  ..... *Bol. areolatus*
- 5b. Basidiospores ridges projecting  $0.5\text{--}1\ \mu\text{m}$ , terminal cells of hyphae in pileipellis  $34\text{--}65 \times 8\text{--}13\ \mu\text{m}$ , sometimes expanded to  $19\ \mu\text{m}$  wide ..... *Bol. rubidus*
- 6a. Pileal surface brown to brownish pink, basidiospores wider measuring  $17\text{--}21 \times 9\text{--}11\ \mu\text{m}$ , and it is associated with pine trees ..... *Bol. squamosus*
- 6b. Pileal surface reddish brown, purplish red to red, basidiospores narrower measuring  $18.5\text{--}21.5 \times 7.5\text{--}9\ \mu\text{m}$ , and it is associated with fagaceous trees ..... *Bol. emodensis*
- 7a. Pileal surface purple, pinkish, pink, reddish, greyish red, red to dark red ..... 8
- 7b. Pileal surface brown ..... 12
- 8a. Pileal surface purple, basidiospores with distinct ridges observed under the light microscope ..... *Bol. violaceus*
- 8b. Pileal surface pinkish, pink, reddish, greyish red, red to dark red, basidiospores nearly smooth or with faintly ridges observed under the light microscope ..... 9
- 9a. Pileal surface pinkish to pink, basidiospores nearly smooth observed under the light microscope ..... *Bol. indistinctus*
- 9b. Pileal surface reddish, greyish red, red to dark red, basidiospores with faint ridges observed under the light microscope ..... 10
- 10a. Hymenophore and context turning blue when injured ..... *Bol. erythrolepis*
- 10b. Hymenophore and context unchanging in colour when injured ..... 11
- 11a. Basidioma comparatively robust, a pileipellis composed of chains of subglobose to globose, few subcylindrical cells, and a distribution in tropical China ..... *Bol. subglobosus*
- 11b. Basidioma comparatively slender, a pileipellis composed of chains of subcylindrical, few subglobose to globose cells, and a distribution in subtropical China ..... *Bol. puniceus*
- 12a. Basidiospores with faint ridges observed under the light microscope ..... *Bol. brunoflavus*
- 12b. Basidiospores with distinct ridges observed under the light microscope ..... 13
- 13a. Basidiospores with fine cross-striations on the ridges observed under the light microscope ..... 14
- 13b. Basidiospores without fine cross-striations on the ridges observed under the light microscope ..... 15
- 14a. Basidiospores larger measuring  $19\text{--}23.5 \times 10.5\text{--}12\ \mu\text{m}$ , and hyphae in pileipellis narrower (up to  $9\ \mu\text{m}$ ) ..... *Bol. fujianensis*
- 14b. Basidiospores smaller measuring  $11.5\text{--}15.5 \times 6.5\text{--}8\ \mu\text{m}$ , and hyphae in pileipellis wider (up to  $16\ \mu\text{m}$ ) ..... *Bol. sinochrysenteroides*
- 15a. Basidiospores longer (up to  $15.5\ \mu\text{m}$ ) ..... 16
- 15b. Basidiospores shorter (up to  $12\ \mu\text{m}$ ) ..... 17

- 16a. Hymenophore and context turning blue, then reddish when injured ..... *Bol. fanjingensis*  
 16b. Hymenophore and context turning blue when injured ..... *Bol. wenshanensis*  
 17a. Basidiospores narrower measuring  $9.5\text{--}11.5 \times 5.5\text{--}6.5\ \mu\text{m}$ , and a pileipellis composed of filamentous hyphae ... *Bol. aff. putuoensis*  
 17b. Basidiospores wider measuring  $9\text{--}12 \times 6\text{--}7.5\ \mu\text{m}$ , and a pileipellis composed of inflated hyphae ..... *Bol. putuoensis*

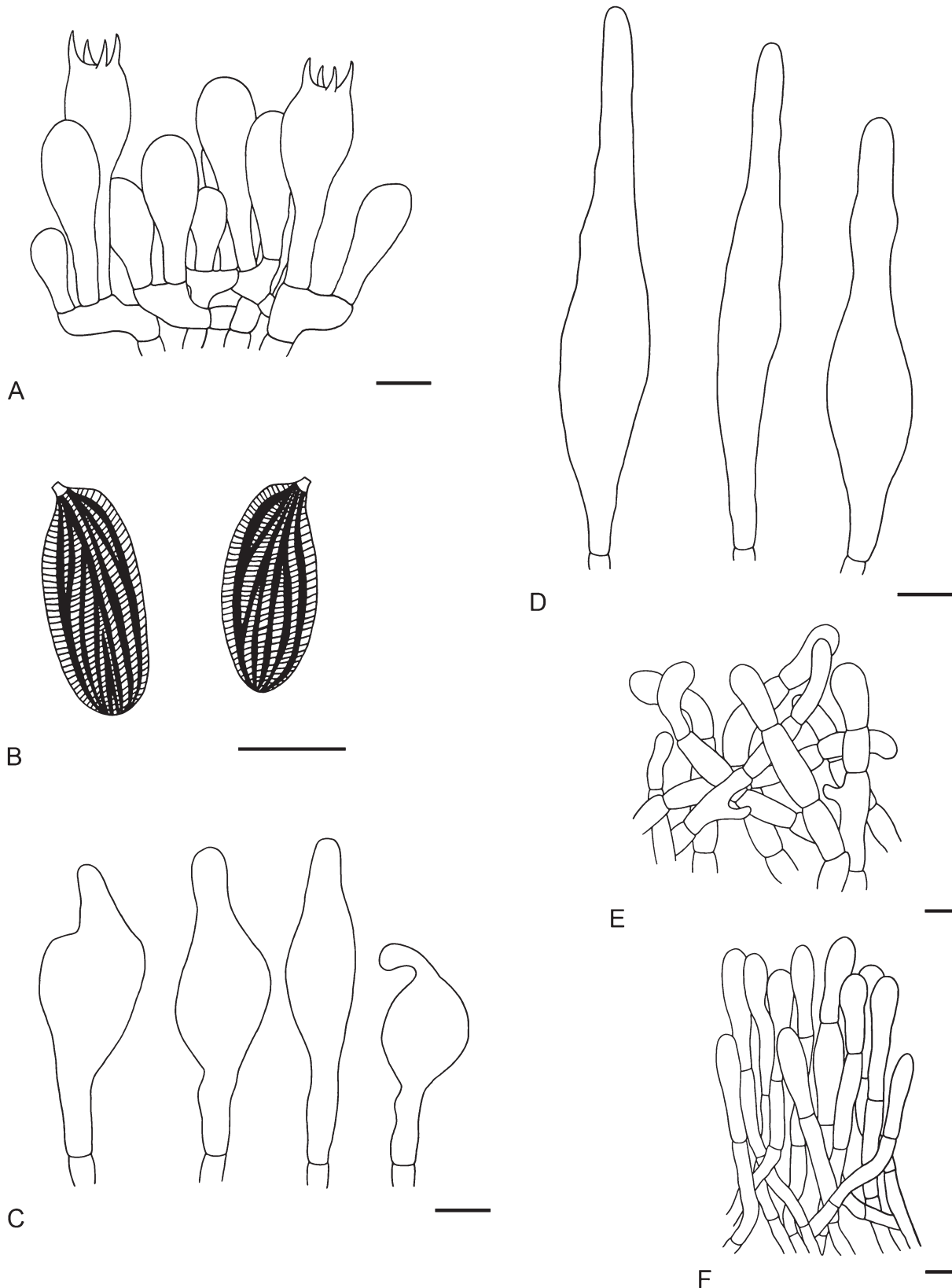


Fig. 43. Microscopic features of *Boletellus zenghuoxingii* (holotype FHMU3251). A. Basidia. B. Basidiospores. C. Cheilocystidia. D. Pleurocystidia. E. Pileipellis. F. Stipitipellis. Scale bars = 10 μm. Drawings by R. Xue.



**Heimioporus** E. Horak, Sydowia 56: 237. 2004.

*Heimioporus*, typified by *H. retisporus*, was erected by Horak (2004) to replace an invalid name, viz., *Heimiella* (Boedijn 1951). It is mainly characterised by a distinctly pitted or alveolate-reticulate to reticulate basidiospore covered by a coarse, net-like ornament (Boedijn 1951, Horak 2004, Halling & Fechner 2011, Wu *et al.* 2016). Until now, four species have been confirmed to be distributed in China (Zeng *et al.* 2018b, Wu *et al.* 2022).

**Heimioporus conicus** N.K. Zeng & Zhu L. Yang, Mycologia 110: 1113. 2018. MycoBank MB 822979.

**Known distribution:** Southern (Hainan Province) and central China (Hunan Province) (Zeng *et al.* 2018).

**Holotype:** FHMU273 (China, Hainan Province).

**Notes:** *Heimioporus conicus* was originally described from Hainan Province, southern China (Zeng *et al.* 2018). Illustrations and a full description of the species have been provided by Zeng *et al.* (2018).

**Heimioporus gaojiaocong** N.K. Zeng & Zhu L. Yang, Mycologia 110: 1113. 2018. MycoBank MB 822980.

**Known distribution:** Southwestern China (Yunnan Province) (Zeng *et al.* 2018).

**Holotype:** FHMU5806 (China, Yunnan Province).

**Notes:** *Heimioporus gaojiaocong* was originally described from Yunnan Province, southwestern China (Zeng *et al.* 2018); illustrations and a full description of the species have been provided by Zeng *et al.* (2018). In China, *Hei. gaojiaocong* was misidentified as *Hei. retisporus* or *Hei. subretisporus* (Wu *et al.* 2016, Zeng *et al.* 2018).

**50. Heimioporus japonicus** (Hongo) E. Horak, Sydowia 56: 238. 2004. MycoBank MB 368253.

**Basionym:** *Heimiella japonica* Hongo, J. Jap. Bot. 44: 237. 1969.

## Key to accepted species of *Heimioporus* in China

- |     |  |                       |
|-----|--|-----------------------|
| 1a. | Stipe surface with reticulations .....   | 2                     |
| 1b. | Stipe surface without reticulations .....  | <i>H. conicus</i>     |
| 2a. | Reticulations on the stipe surface overlaid by yellow squamules .....  | <i>H. gaojiaocong</i> |
| 2b. | Reticulations on the stipe surface overlaid by red squamules .....   | 3                     |
| 3a. | Basidiospores narrower measuring 11–14 × 7–8 µm, surface completely reticulate, globoid to oblong terminal cells in pileipellis .....  | <i>H. japonicus</i>   |
| 3b. | Basidiospores wider measuring 11.5–13.5 × 8–9.5 µm, surface incompletely reticulate to reticulate-alveolate, cylindrical to narrowly clavate-subcapitate terminal cells in pileipellis ..... | <i>H. sinensis</i>    |

**Hemileccinum** Šutara, Czech Mycol. 60: 52. 2008.

*Hemileccinum*, typified by *H. impositum*, is mainly characterised by a lateral stipe stratum of the leccinoid type, and irregularly warty basidiospores under SEM (Šutara 2008, Wu *et al.* 2014, 2016, Li *et al.* 2021). Besides one new species described in the present study, six species have been confirmed to be distributed in China (Wu *et al.* 2016, Li *et al.* 2021).

**Synonyms:** *Boletellus japonicus* (Hongo) L.D. Gómez, Revista Biol. Trop. 44: 71. 1997.

*Heimioporus xerampelinus* (M. Zang & W.K. Zheng) E. Horak, Sydowia 56: 239. 2004.

*Boletellus xerampelinus* M. Zang & W.K. Zheng, Acta Bot. Yunnan. 7: 394. 1985.

*Boletellus xerampelinus* M. Zang & W.K. Zheng, Acta Bot. Yunnan. 8: 21. 1986.

**Known distribution:** Southeastern (Fujian Province), southwestern (Yunnan Province), and southern China (Hainan Province); Japan, Thailand (Hongo 1969, Raspé *et al.* 2016, Zeng *et al.* 2018).

**Materials examined:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 845 m, 29 Jul. 2009, N.K. Zeng, Zeng398 (FHMU231); Jianfengling of Hainan Tropical Rainforest National Park, elev. 850 m, 3 Jul. 2014, N.K. Zeng, Zeng1566 (FHMU4431); Fujian Province, Zhangping County, Tiantai National Forest Park, elev. 380 m, 28 Aug. 2009, N.K. Zeng, Zeng581, 584, 636 (FHMU366, 368, 400); Yunnan Province, Wuding County, bought from a market selling fresh wild mushrooms, 19 Aug. 2016, N.K. Zeng, Zeng2786, 2793 (FHMU4433, 4409).

**Notes:** *Heimioporus japonicus* was originally described from Japan (Hongo 1969), then reported from China (Zeng *et al.* 2018). Illustrations and a full description of the species have been provided by Hongo (1969) and Zeng *et al.* (2018).

**Heimioporus sinensis** Ming Zhang *et al.*, Phytotaxa 415: 182. 2019. MycoBank MB 829110.

**Known distribution:** Southern (Guangdong Province) and central China (Hunan Province) (Chen *et al.* 2019).

**Holotype:** GDGM45162 (China, Guangdong Province).

**Notes:** *Heimioporus sinensis* was originally described from Guangdong Province, southern China (Chen *et al.* 2019). Illustrations and a full description of the species have been provided by Chen *et al.* (2019).

**Hemileccinum albidum** Mei Xiang Li *et al.*, Journal of Fungi 7: 8. 2021. MycoBank MB 840704.

**Known distribution:** Southwestern China (Yunnan Province) (Li *et al.* 2021).

**Holotype:** KUN-HKAS81120 (China, Yunnan Province).





Fig. 44. Basidiomata of *Hemileccinum* species. A–C. *H. ferrugineipes* (A. FHMU2270; B. FHMU894; C. FHMU1939). D–F. *H. rugosum* (FHMU2966). G–I. *H. squamipes* (G, H. FHMU1679; I. holotype FHMU4902). Photos by N.K. Zeng.

*Notes:* *Hemileccinum albidum* was originally described from Yunnan Province, southwestern China (Li *et al.* 2021). Illustrations and a full description of the species have been provided by Li *et al.* (2021).

***Hemileccinum brevisporum*** Mei Xiang Li *et al.*, Journal of Fungi 7: 11. 2021. MycoBank MB 840701.

*Known distribution:* Southwestern China (Yunnan Province) (Li *et al.* 2021).

*Holotype:* KUN-HKAS89150 (China, Yunnan Province).

*Notes:* *Hemileccinum brevisporum* was originally described from Yunnan Province, southwestern China (Li *et al.* 2021). Illustrations and a full description of the species have been provided by Li *et al.* (2021).

***Hemileccinum ferrugineipes*** Mei Xiang Li *et al.*, Journal of Fungi 7: 13. 2021. MycoBank MB 840700. Figs 44A–C, 46.

*Description:* Basidiomata small to medium-sized. *Pileus* 3.7–5.7 cm diam, subhemispherical when young, then convex to applanate, margin decurved; surface dry, subtomentose, yellowish brown to reddish brown; context 0.3–0.9 cm thick in the centre of the pileus, yellowish white to yellowish, unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores subround, 0.3–0.5 mm diam, yellow, unchanging in colour when injured; tubes 0.4–0.6 cm in length, yellowish, unchanging in colour when injured. *Stipe* 4.5–8.5 × 0.4–1 cm, central, subcylindric; surface reddish brown to dark reddish brown, but light yellow at the apex, densely covered with small, white scales; context upper part pale yellow, lower part reddish brown, unchanging in colour when injured; basal mycelium white. *Odour* indistinct.



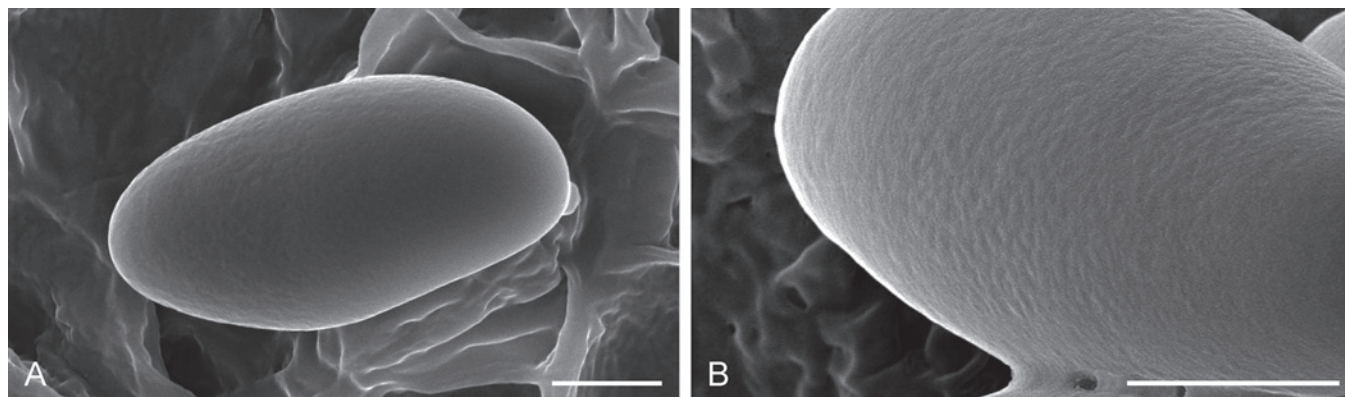


Fig. 45. Basidiospores of *Hemileccinum squamipes* from herbarium materials under SEM (holotype FHMU4902). Photos by C. Xu.

*Basidia* 22–33 × 9–11 µm, clavate, thin- to slightly thick-walled (up to 1 µm), 4-spored, colourless to yellowish in KOH; sterigmata 2–4 µm long *Basidiospores* [80/4/4] (9–)10–11(–12) × (3.5–)4–5 µm,  $Q = (2.0\text{--})2.10\text{--}2.86\text{--}(3.0)$ ,  $Q_m = 2.47 \pm 0.24$ , subfusiform, slightly thick-walled (up to 1 µm), yellowish brown in KOH, smooth under light microscopy, but with tiny warts on the surface under SEM. . *Hymenophoral trama* composed of thin- to slightly thick-walled (up to 0.5 µm) hyphae, 5–12 µm wide, yellowish in KOH. *Cheilocystidia* 19–30 × 7–12 µm, subfusiform or fusiform, thin-walled, yellowish in KOH. *Pleurocystidia* 31–60 × 9–10 µm, subfusiform, thin-walled, yellowish in KOH. *Pileipellis* is a hyphoepithelium 120–130 µm thick, composed of chains of subglobose to pyriform cells up to 29 µm in width, thin-walled, brownish yellow in KOH, 2.5–5 µm in width; terminal cell 7–29 × 2–15 µm, clavate or subcylindrical. *Pileal trama* made up of hyphae 2–4 µm diam, thin-walled, yellow in KOH. *Stipitipellis* is a trichoderm-like structure 70–130 µm thick, composed of thin-walled, 3–9 µm wide, yellowish brown in KOH, emergent hyphae with subfusiform or clavate terminal cells (24–47 × 5–11 µm). *Stipe trama* composed of cylindrical, yellow in KOH, thin-walled hyphae, 3–12 µm wide. *Clamp connections* absent in all tissues.

*Habitat*: Scattered on the ground in forests dominated by fagaceous trees.

*Known distribution*: Southern (Hainan Province), southeastern (Fujian Province), and southwestern China (Yunnan Province) (Li *et al.* 2021).

*Holotype*: KUN-HKAS115554 (China, Yunnan Province).

*Materials examined*: **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 26 May 2017, N.K. Zeng, Zeng2978 (FHMU1939); Fujian Province, Zhangping City, Xinqiao Town, Chengkou Village, elev. 350 m, 1 Aug 2013, N.K. Zeng, Zeng1342 (FHMU894); same location, 22 Aug. 2017, N.K. Zeng, Zeng3309-1 (FHMU7597); Yunan Province, Nanhua County, bought from market, 22 Aug 2017, Y.J. Pu, Pu286 (FHMU7591).

*Notes*: *Hemileccinum ferrugineipes* was originally described from Yunnan Province, southwestern China (Li *et al.* 2021). In the present study, it was also found to be distributed in Hainan and Fujian Provinces of China. The species is characterised by a small to medium-sized basidioma, a subtomentose, yellowish brown to reddish brown pileus, hymenophore and context unchanging in colour when injured, and a stipe densely covered with white scales. We also noted that the stipe surface was described as “yellowish

to yellow at upper part, lower part pale red-brown of stipe pileus; covered with longitudinal striations and densely dotted scales” by Li *et al.* (2021), which is somewhat different from our new specimens.

***Hemileccinum indecorum*** (Massee) G. Wu & Zhu L. Yang, Fungal Diversity 81: 98. 2016. MycoBank MB 818459.

*Basionym*: *Boletus indecorus* Massee, Bull. Misc. Inform. Kew. 1914: 75. 1914.

*Synonyms*: *Comeroboletus indecorus* (Massee) N.K. Zeng & Zhu L. Yang, Mycologia 104: 1423. 2011.

*Boletus umbilicatus* Massee, Bull. Misc. Inform. Kew. : 205.1909 (*nom. illeg.*, later homonym); *non Boletus umbilicatus* Scop., Fl. Carniol., Edn 2 (Wien) 2: 466. 1772; *non Boletus umbilicatus* Schrank, Baier. Fl. (München) 2: 621. 1789.

*Pulveroboletus umbilicatus* (Massee) Singer, Agaric. Mod. Taxon.: 729. 1975 (*comb. illeg.*).

*Boletopsis corrugatus* Pat. & C.F. Baker, J. Straits Branch Roy. Asiat. Soc. 78: 68. 1918.

*Pulveroboletus corrugatus* (Pat. & C.F. Baker) Singer, Amer. Midl. Naturalist. 37: 11. 1947.

*Pulveroboletus corrugatus* (Pat. & C.F. Baker) Watling *et al.*, Bull. Soc. Mycol. Fr. 122: 327. 2006 (*comb. superfl.*).

*Known distribution*: Southern China (Hainan Province); Singapore, Malaysia (Corner 1972, Zeng *et al.* 2012, Wu *et al.* 2016).

*Holotype*: K 171145 (Singapore).

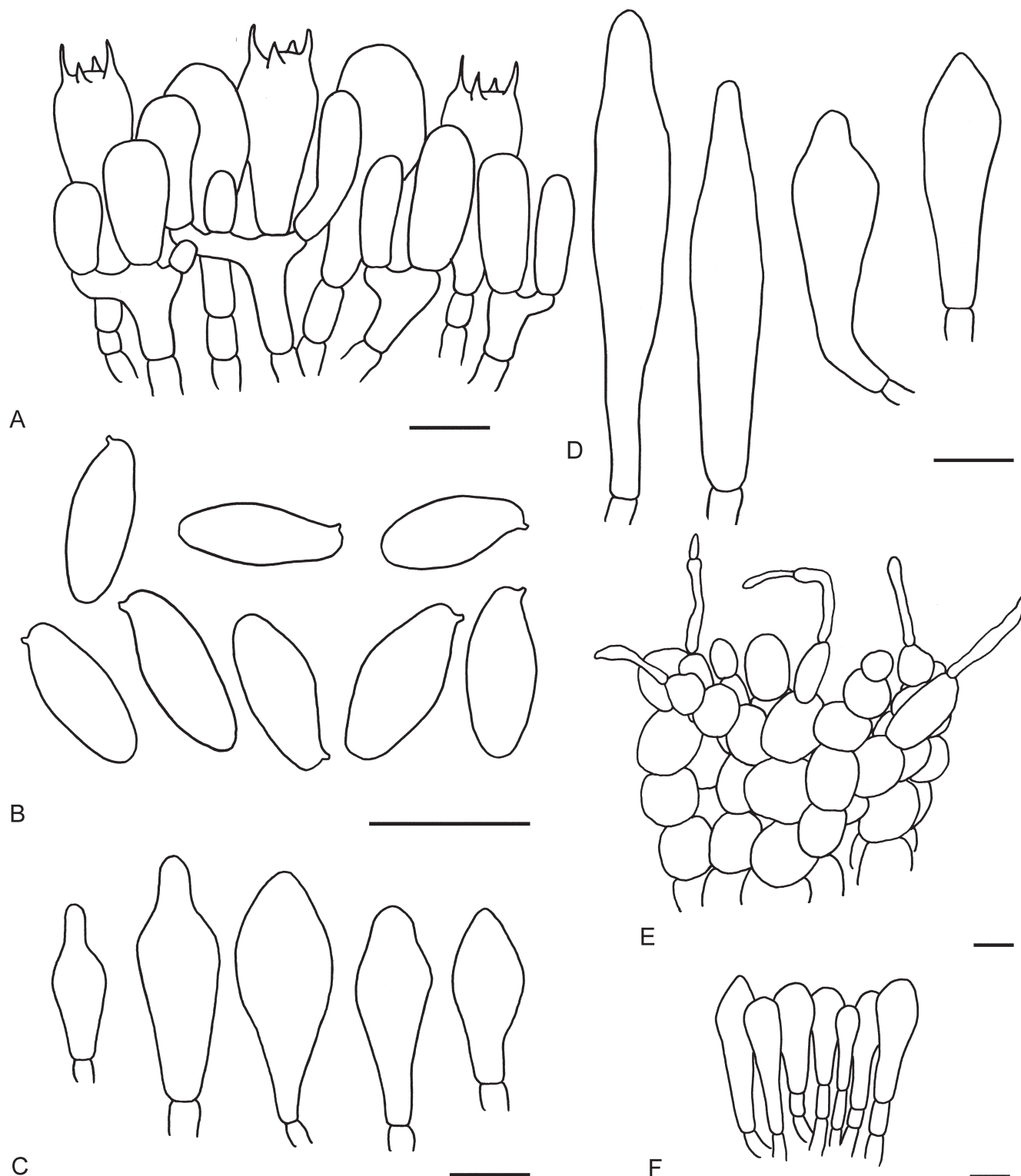
*Materials examined*: **China**, Hainan Province, Limushan of Hainan Tropical Rainforest National Park, elev. 630 m, 4 Jun. 2009, N.K. Zeng, Zeng244 (KUN-HKAS63126); same location, 5 Aug. 2010, N.K. Zeng, Zeng851 (KUN-HKAS63127).

*Notes*: *Hemileccinum indecorum* was originally described from Singapore (Corner 1972); illustrations and a full description of the species have been provided by Corner (1972) and Zeng *et al.* (2012). The phylogenetic position of the species was ambiguous in the past (Zeng *et al.* 2012). Recently, the species was transferred to *Hemileccinum* according to the results of phylogenetic analyses (Wu *et al.* 2016).

***Hemileccinum parvum*** Mei Xiang Li *et al.*, Journal of Fungi 7: 15. 2021. MycoBank MB 840703.

*Known distribution*: Southwestern China (Yunnan Province) (Li *et al.* 2021).





**Fig. 46.** Microscopic features of *Hemileccinum ferrugineipes* (FHMU1939). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10  $\mu$ m. Drawings by Z. Li.

*Holotype:* KUN-HKAS115553 (China, Yunnan Province).

*Notes:* *Hemileccinum parvum* was originally described from Yunnan Province, southwestern China (Li *et al.* 2021); illustrations and a full description of the species have been provided by Li *et al.* (2021).

***Hemileccinum rugosum*** G. Wu & Zhu L. Yang, Fungal Diversity 81: 97. 2016. MycoBank MB 818458. Figs 44D–F, 47.

*Description:* *Basidiomata* medium-sized. *Pileus* 5–5.4 cm diam, subhemispherical when young, then convex to applanate, margin uneven; surface dry, rugose, pale brown to brown; context about 1 cm thick in the centre of the pileus, yellowish, unchanging in colour when injured. *Hymenophore* poroid, slightly depressed around apex of stipe; pores angular, about 0.1 mm diam, yellow, unchanging in colour when injured; tubes about 0.8 cm in length, yellowish, unchanging in colour when injured. *Stipe* 5.2–7.4  $\times$  0.8–1 cm, central, solid, subcylindric; surface white, densely covered with

minute, pale brown scales; context yellowish white, unchanging in colour when injured; basal mycelium white. *Odour* indistinct.

*Basidia* 24–26 × 9–11 µm, clavate, thin-walled, 4-spored, colourless in KOH; sterigmata 3–5 µm long. *Basidiospores* [40/2/1] 10–11.5 × 4–5 µm,  $Q = 2.20\text{--}2.75$ ,  $Q_m = 2.43 \pm 0.21$ , subfusiform, slightly thick-walled (up to 0.7 µm), yellowish brown in KOH, smooth under light microscopy, but with tiny warts on the surface under SEM. *Hymenophoral trama* composed of thin-walled hyphae, 4–9.5 µm wide, yellowish in KOH. *Cheilocystidia* 19–39 × 5–10 µm, subfusiform or fusiform, thin-walled, colourless to yellowish in KOH. *Pleurocystidia* 33–58 × 8–10 µm, subfusiform, thin-walled, colourless to yellowish in KOH. *Pileipellis* a hyphoepithelium 110–160 µm thick, composed of chains of subglobose to pyriform cells up to 29 µm in width, thin-walled, pale yellow to yellow in KOH; terminal cell 6–29 × 3–9 µm, clavate or subcylindrical. *Pileal trama* made up of hyphae 5–20 µm diam, thin-walled, hyaline to yellowish in KOH. *Stipitipellis* a trichoderm-like structure 50–90 µm thick, composed of thin-walled, 2–6 µm wide, colourless in KOH, emergent hyphae with clavate terminal cells (15–32 × 6–12 µm). *Stipe trama* composed of cylindrical, yellowish in KOH, thin-walled, hyphae 5–10 µm wide. *Clamp connections* absent in all tissues.

*Habitat*: Scattered on the ground in forests dominated by fagaceous trees.

*Known distribution*: Southern China (Hainan Province) and southwestern China (Yunnan Province) (Wu *et al.* 2016).

*Holotype*: KUN-HKAS84355 (China, Yunnan Province).

*Materials examined*: **China**, Hainan Province, Jianfengling of Hainan Tropical Rainforest National Park, elev. 850 m, 27 Jun. 2018, N.K. Zeng, Zeng3388 (FHMU2966).

*Notes*: *Hemileccinum rugosum* was originally described from Yunnan Province, southwestern China (Wu *et al.* 2016). In the present study, it was also found to be distributed in Hainan Province, tropical China. The species is characterised by a medium-sized basidioma, a rugose, pale brown to brown pileus, hymenophore and context unchanging in colour when injured, and a stipe densely covered with minute, pale brown scales. We also noted that the pileal surface was described as “light orange to reddish orange” by Wu *et al.* (2016) whereas our new collection is pale brown to brown. Interestingly, judging from the photos of the holotype of *H. rugosum* (Wu *et al.* 2016), the pileal surface is also brown, with no orange tint.

**58. *Hemileccinum squamipes*** N.K. Zeng, Chang Xu & Zhi Q. Liang, *sp. nov.* MycoBank MB 846895. Figs 44G–I, 45, 48.

*Etymology*: *squamipes* (Lat.), refers to the squamules on the stipe.

*Diagnosis*: Differs from other species of *Hemileccinum* by a pale brown to brown, rugose pileal surface, a stipe densely covered with yellow to brown squamules, and smaller basidiospores measuring 10–11 × 4–5 µm.

*Typus*: **China**, Hainan Province, Jianfengling of Hainan Tropical Rainforest National Park, elev. 650 m, 10 Aug. 2020, N.K. Zeng, Zeng4586 (*holotype* FHMU4902).

*Additional materials examined*: **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 550 m, 5 Aug. 2015,

N.K. Zeng, Zeng2572 (FHMU1679); Yunnan Province, Jingping County, Fenshuiling National Nature Reserve, elev. 1 200 m, 12 Jul. 2018, N.K. Zeng, Zeng3555 (FHMU3069).

*Description*: *Basidiomata* small to medium-sized. *Pileus* 2.8–6 cm diam, subhemispherical when young, then applanate, margin incurved; surface slightly viscid when wet, rugose, pale brown to brown (5E5); context 0.3–0.5 cm thick in the centre of the pileus, yellowish white (1A2), unchanging in colour when injured. *Hymenophore* poroid, slightly depressed around apex of stipe; pores angular, 0.3–1 mm diam, yellow (1A4), unchanging in colour when injured; tubes about 0.3 cm in length, pale yellow, unchanging in colour when injured. *Stipe* 6.5–8 × 0.7–1 cm, central, subcylindric; surface white, covered with yellow (2A4) to brown (5D3) squamules; context yellow (2A3), sometimes tinged with brown (5D2), unchanging in colour when injured; basal mycelium white (1A1). *Odour* indistinct.

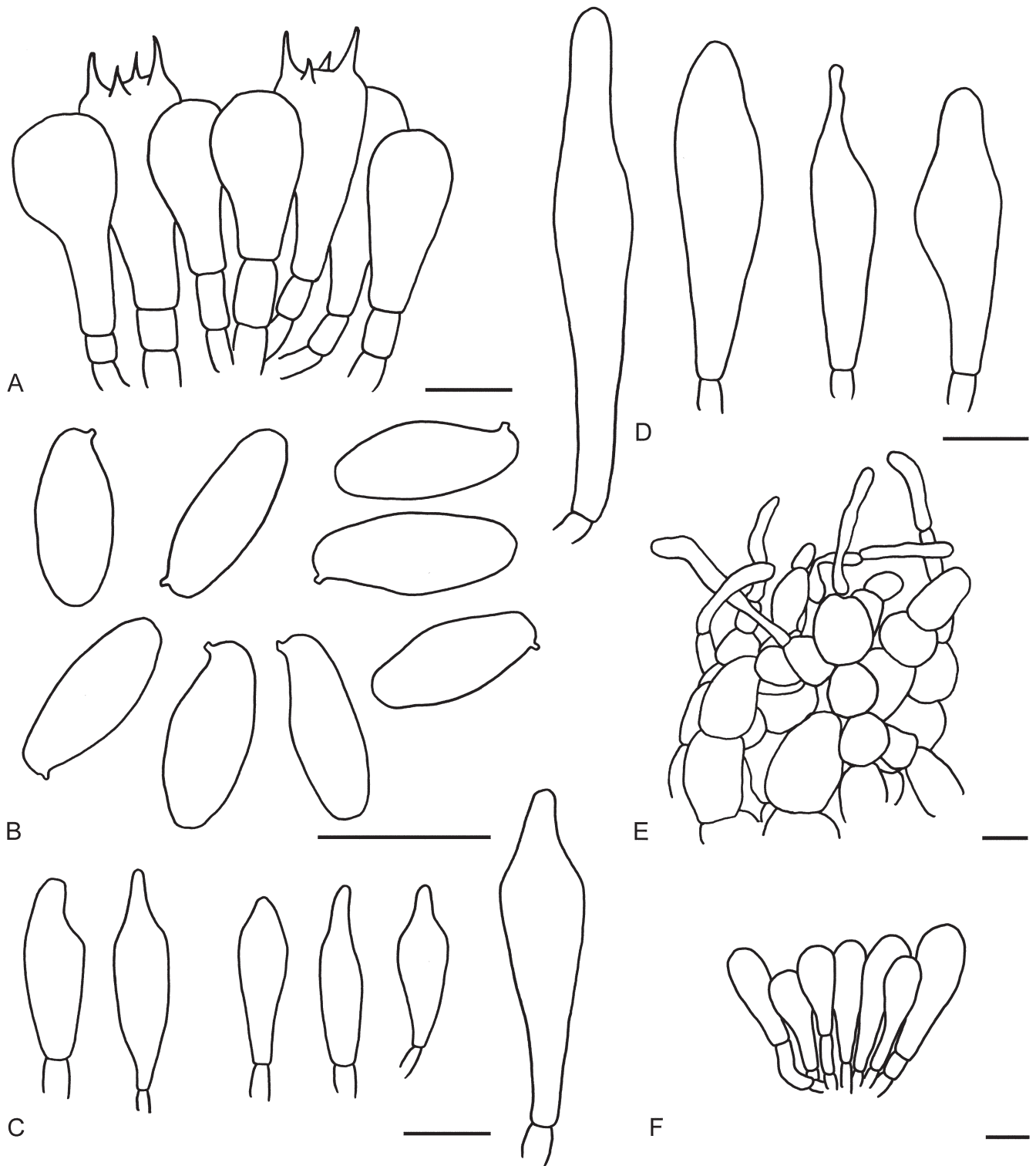
*Basidia* 30–38 × 9–11 µm, clavate, thin- to slightly thick-walled (up to 1 µm), 4-spored, colourless to pale yellow in KOH; sterigmata 2–4 µm long. *Basidiospores* [60/3/3] 10–11(–11.5) × 4–5 µm,  $Q = 2.10\text{--}2.75$ (–3.14),  $Q_m = 2.46 \pm 0.28$ , fusoid, slightly thick-walled (up to 1 µm), yellowish brown in KOH, smooth under light microscopy, but with tiny warts on the surface under SEM. *Hymenophoral trama* composed of thin-walled hyphae, 5–10 µm wide, yellowish in KOH. *Cheilocystidia* 26–53 × 8–15 µm, subfusiform or fusiform, thin-walled, colourless in KOH. *Pleurocystidia* 35–52 × 9–12 µm, subfusiform or fusiform, thin-walled, colourless in KOH. *Pileipellis* a hyphoepithelium 150–460 µm thick, composed of chains of subglobose to pyriform cells up to 17 µm in width, thin- to slightly thick-walled (up to 1 µm), lemon yellow in KOH; terminal cell 4–17 × 3.5–14 µm, subspherical, spherical, clavate, or subfusiform, with obtuse, occasionally acute apex. *Pileal trama* made up of hyphae 4–15.5 µm diam, thin- to slightly thick-walled (up to 1 µm), hyaline to yellowish in KOH. *Stipitipellis* a trichoderm-like structure 98–145 µm thick, composed of thin- to slightly thick-walled (up to 1 µm), 5–12 µm wide, colourless to yellow in KOH, emergent hyphae with subfusiform, subcylindrical or clavate terminal cells (17–38 × 6–11 µm). *Stipe trama* composed of cylindrical, hyaline to yellowish in KOH, slightly thick-walled (up to 0.5 µm) hyphae 4–13 µm wide. *Clamp connections* absent in all tissues.

*Habitat*: Scattered in the forests dominated by fagaceous trees.

*Known distribution*: Southern (Hainan Province) and southwestern China (Yunnan Province).

*Notes*: Morphologically, *H. squamipes* is similar to *H. albidum*, *H. brevisporum*, and *H. parvum*, three taxa originally described from Yunnan Province, southwestern China (Li *et al.* 2021). However, *H. albidum* has a whitish, nearly smooth stipe with only small, granular scales at the base, and larger basidiospores measuring 10–12.5 × 4.0–5.5 µm (Li *et al.* 2021); *H. brevisporum* has a pileus tinged with reddish, a long stipe (13–15 × 2.0–2.3 cm), and small basidia measuring 18.5–27 × 8–11 µm (Li *et al.* 2021); *H. parvum* has a smaller basidioma (pileus only up to 3.6 cm diam), a pileal context turning blue when injured, a pale yellow stipe, and longer basidiospores measuring 12–14 × 4.5–5 µm (Li *et al.* 2021).

*Hemileccinum squamipes* is also morphologically similar to North American *H. floridanum*, *H. hortonii*, and *H. subglabripes*. However, *H. floridanum* has a larger basidioma (pileus up to 12.5 cm diam), a pileal surface usually tinged with reddish, and larger basidiospores measuring 13–16 × 4.5–6 µm (Farid *et al.* 2021);



**Fig. 47.** Microscopic features of *Hemileccinum rugosum* (FHMU2966). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10  $\mu$ m. Drawings by Z. Li.

*H. hortonii* has a larger basidioma (pileus up to 12 cm diam), a pileal surface uneven to corrugated or alveolate, usually tinged with reddish, and longer but narrower basidiospores measuring 12–15  $\times$  3.5–4.5  $\mu$ m (Smith & Thiers 1971, Kuo & Ortiz-Santana 2020);

*H. subglabripes* has a stipe yellow at first, then slowly developing red colours from the base upwards, and longer basidiospores measuring 11–14  $\times$  3–5  $\mu$ m (Smith & Thiers 1971, Halling *et al.* 2020).

### Key to accepted species of *Hemileccinum* in China

- 1a. Pileal surface with conical, subconical to irregularly shaped squamules, a presence of a zone on the stipe ..... *H. indecorum*  
 1b. Pileal surface slightly subtomentose, rugose to wrinkled, an absence of a zone on the stipe ..... 2



- 2a. Pileus smaller (up to 4 cm in diam), pileal context turning pale blue very slowly when injured at some spots ..... *H. parvum*  
 2b. Pileus larger (> 4 cm in diam), pileal context unchanging in colour when injured ..... 3
- 3a. Stipe surface whitish or whitish brown ..... 4  
 3b. Stipe surface yellowish to yellow at upper part, pale yellowish brown to reddish brown at lower part ..... 5
- 4a. Pileal surface distinctively rugose when mature ..... *H. rugosum*  
 4b. Pileal surface smooth when mature ..... *H. albidum*
- 5a. Pileal surface pale brown to brown, without reddish tinge ..... *H. squamipes*  
 5b. Pileal surface yellowish brown tinged with reddish ..... 6
- 6a. Stipe surface cream to yellowish at upper part, pale yellowish brown to yellowish brown at lower part, covered with yellowish brown scales ..... *H. brevisporum*  
 6b. Stipe surface reddish brown to dark reddish brown, but light yellow at the apex, densely covered with white scales .. *H. ferrugineipes*

**Hourangia** Xue T. Zhu & Zhu L. Yang, Mycol. Progr. 14: 3. 2015.

*Hourangia*, typified by *Hou. cheoi*, is characterised by a context of the stipe turning bluish firstly, then reddish to brownish red, and finally brownish to blackish when injured, a thick hymenophore being 3–5 (–7) times that of the pileal context, and the basidiospore surface with bacillate ornamentation (Zhu *et al.* 2015). Until now, four species have been confirmed to distribute in China (Zhu *et al.* 2015, Gelardi *et al.* 2017, Wang *et al.* 2020).

**59. *Hourangia cheoi*** (W.F. Chiu) Xue T. Zhu & Zhu L. Yang, Mycol. Progr. 14: 5. 2015. MycoBank MB 810696.

*Basionym*: *Boletus cheoi* W.F. Chiu, Mycologia 40: 215. 1948.

*Synonyms*: *Xerocomus cheoi* (W.F. Chiu) F.L. Tai, Syll. Fung. Sinicorum: 813. 1979.

*Boletus punctilifer* W.F. Chiu, Mycologia 40: 216. 1948.

*Xerocomus punctilifer* (W.F. Chiu) F.L. Tai, Syll. Fung. Sinicorum: 814. 1979.

*Known distribution*: Southwestern China (Yunnan Province) (Chiu 1948, Zhu *et al.* 2015, Gelardi *et al.* 2017).

*Epitype*: KUN-HKAS52269 (China, Yunnan Province).

*Material examined*: **China**, Yunnan Province, Jingdong County, elev. 2 500 m, 20 Jul. 2006, Z.L. Yang, Yang4683 (KUN-HKAS50480)

*Notes*: *Hourangia cheoi* was originally described from Yunnan Province, southwestern China (Chiu 1948). It was placed in the genus *Boletus* firstly (Chiu 1948), and later transferred to *Xerocomus* (Tai 1979). One recent study indicated it is a member of *Hourangia* (Zhu *et al.* 2015). Illustrations and a full description of the species have been provided by Zhu *et al.* (2015) and Gelardi *et al.* (2017).

***Hourangia densisquamata*** N.K. Zeng *et al.*, Phytotaxa 472: 95, 2020. MycoBank MB 835901.

*Known distribution*: Southeastern China (Fujian Province) (Wang *et al.* 2020).

*Holotype*: FHMU855 (China, Fujian Province).

*Notes*: *Hourangia densisquamata* was originally described from Fujian Province, southeastern China (Wang *et al.* 2020). Illustrations and a full description of the species have been provided by Wang *et al.* (2020).

**61. *Hourangia dilatata*** N.K. Zeng *et al.*, Phytotaxa 472: 98. 2020. MycoBank MB 835943.

*Known distribution*: Southern (Hainan Province) and southeastern China (Fujian Province) (Wang *et al.* 2020).

*Holotype*: FHMU2979 (China, Hainan Province).

*Notes*: *Hourangia dilatata* was originally described from Hainan Province, southern China (Wang *et al.* 2020); illustrations and a full description of the species have been provided by Wang *et al.* (2020). In China, *Hou. dilatata* was misidentified as *Hou. microcarpa* (Zhu *et al.* 2015, Wang *et al.* 2020).

**62. *Hourangia nigropunctata*** (W.F. Chiu) Xue T. Zhu & Zhu L. Yan, Mycol. Progr. 14: 7. 2015. MycoBank MB 810697.

*Basionym*: *Boletus nigropunctatus* W.F. Chiu, Mycologia 40: 214. 1948.

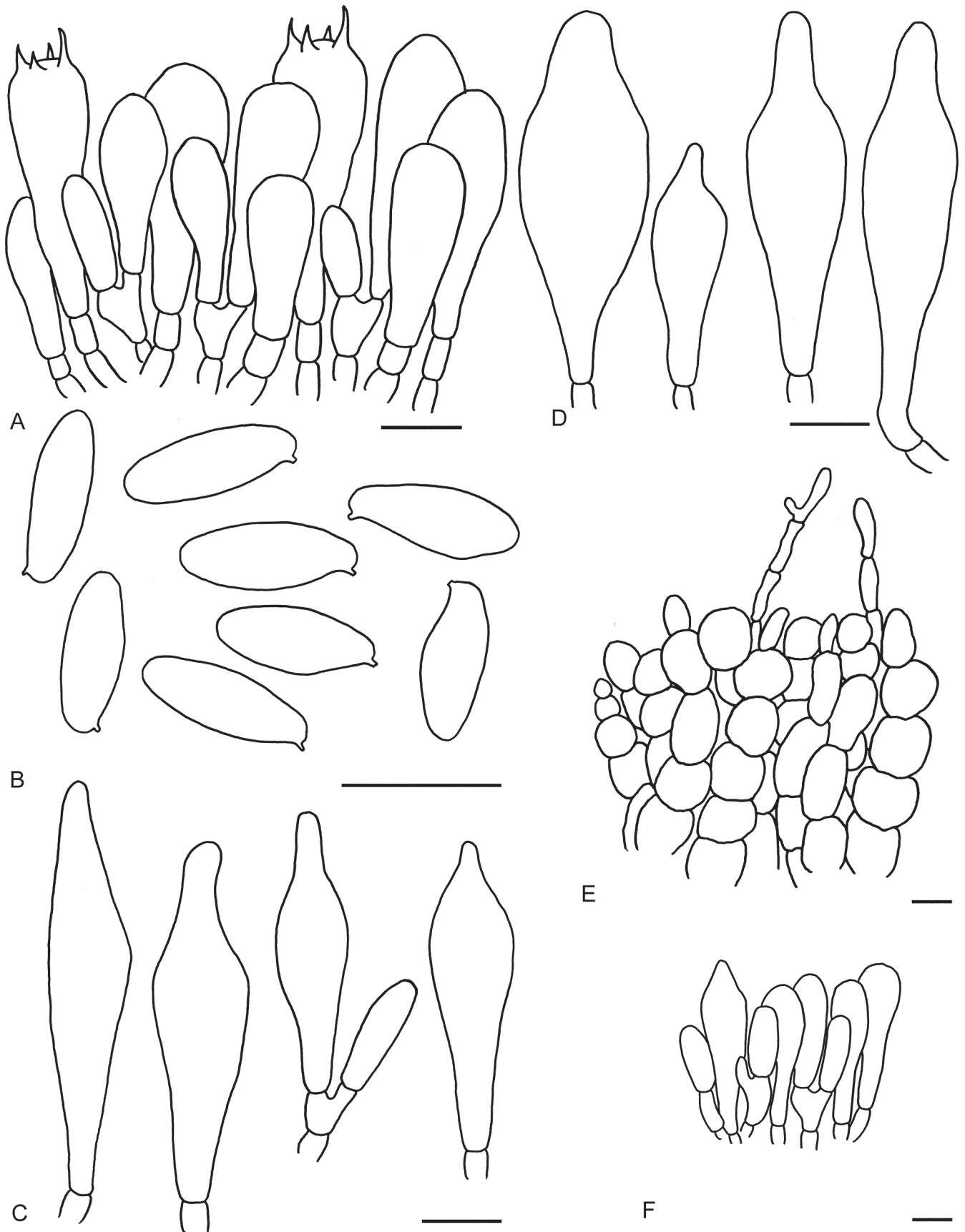
*Synonym*: *Xerocomus nigropunctatus* (W.F. Chiu) F.L. Tai, Syll. Fung. Sinicorum: 813. 1979.

*Known distribution*: Southwestern (Sichuan and Yunnan Provinces), central (Hunan Province), southeastern (Fujian Province), and southern China (Guangxi and Hainan Provinces) (Zhu *et al.* 2015, Wang *et al.* 2020).

*Epitype*: KUN-HKAS76657 (China, Guizhou Province).

*Material examined*: **China**, Fujian Province, Sanming City, Sanyuan National Forest Park, 25 Aug. 2007, Y.C. Li, Li1010 (KUN-HKAS53355).

*Notes*: *Hourangia nigropunctata* was originally described from Sichuan Province, southwestern China (Chiu 1948). It was placed in the genus *Boletus* firstly (Chiu 1948), and later transferred to *Xerocomus* (Tai 1979). One recent study indicated it is a member of *Hourangia* (Zhu *et al.* 2015). Illustrations and a full description of the species have been provided by Zhu *et al.* (2015) and Wang *et al.* (2020). The species is common in subtropical and tropical China (Zhu *et al.* 2015, Wang *et al.* 2020).



**Fig. 48.** Microscopic features of *Hemileccinum squamipes* (holotype FHMU4902). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10 µm. Drawings by Z. Li.



## Key to accepted species of *Hourangia* in China

- 1a. Basidiospores longer (up to 12.5  $\mu\text{m}$ ), pileal context changing to blue quickly and distinctly when injured ..... *H. cheoi*  
 1b. Basidiospores shorter (up to 11  $\mu\text{m}$ ), pileal context changing slightly to blue or unchanging in colour when injured ..... 2
- 2a. Basidiomata smaller ( $\leq 2.5$  cm) ..... *H. dilatata*  
 2b. Basidiomata larger ( $> 2.5$  cm) ..... 3
- 3a. Basidiospores smaller ( $7\text{--}9.5 \times 3.5\text{--}4.5$   $\mu\text{m}$ ,  $Q_m = 1.98 \pm 0.20$ ), pileal context changing to blue slightly, then to reddish when injured, stipe surface without a layer of white pruina ..... *H. nigropunctata*  
 3b. Basidiospores larger ( $9\text{--}11 \times 4\text{--}5$   $\mu\text{m}$ ,  $Q_m = 2.36 \pm 0.20$ ), pileal context unchanging in colour or changing slightly to blue when injured, stipe surface covered with a layer of white pruina ..... *H. densisquamata*

***Phylloporus*** Quél., Fl. mycol. France (Paris): 409. 1888.

*Phylloporus*, typified by *P. pelletieri*, is characterised by having a gilled hymenophore (Binder & Bresinsky 2002, Neves & Halling 2010, Neves *et al.* 2012). Besides revealing one new *Phylloporus* species in the present study, 24 species have been confirmed to distribute in China (Zang & Zeng 1978, Zeng *et al.* 2013, Zhao *et al.* 2018, Chuankid *et al.* 2019, Wu *et al.* 2021).

***Phylloporus alboinfuscatus*** N.K. Zeng *et al.*, Mycol. Progr. 20: 1253. 2021. MycoBank MB 838739.

**Known distribution:** Central (Hunan Province) and southern China (Guangdong and Hainan Provinces) (Wu *et al.* 2021).

**Holotype:** FHMU3276 (China, Hunan Province).

**Materials examined:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 14 Aug. 2020, N.K. Zeng, Zeng4783, 4784, 4787 (FHMU5428, 5408, 5450).

**Notes:** *Phylloporus alboinfuscatus* was originally described from Hunan Province, central China (Wu *et al.* 2021); illustrations and a full description of the species have been provided by Wu *et al.*



**Fig. 49.** Basidiomata of *Phylloporus* species. **A, B.** *P. hainanensis* (holotype FHMU1718). **C, D.** *P. pusillus* (FHMU5010). Photos by N.K. Zeng.



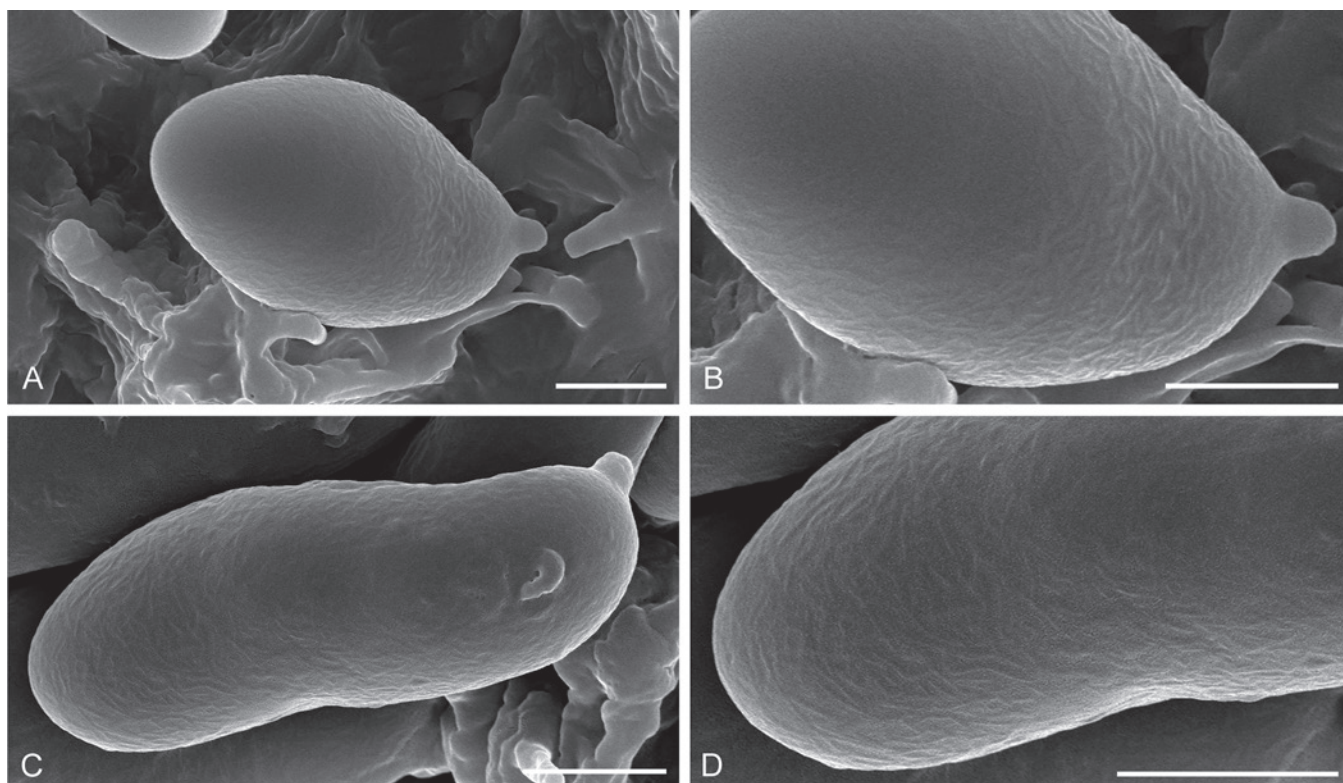


Fig. 50. Basidiospores of *Phyloporus* species from herbarium materials under SEM. A, B. *P. hainanensis* (FHMU4723). C, D. *P. pusillus* (FHMU3361). Photos by C. Xu.

(2021). The Hainan specimens cited above extends the range of distribution and is the first report from tropical China.

***Phyloporus bellus*** (Massee) Corner, Nova Hedwigia 20 (3–4): 798. 1970. MycoBank MB 320285.

*Basionym*: *Flammula bella* Massee, Bull. Misc. Inf., Kew: 74. 1914.

*Known distribution*: Southwestern (Yunnan Province) and southern China (Guangdong and Hainan Provinces); Singapore, Malaysia, New Guinea, Korea, Japan, Philippines, and India (Massee 1914, Corner 1970, Zeng *et al.* 2013, Acharya *et al.* 2017).

*Materials examined*: **China**, Hainan Province, Wuzhishan of Hainan Tropical Rainforest National Park, elev. 650 m, 12 Aug. 2020, N.K. Zeng, Zeng4625, 4629, 4655 (FHMU4994, 4978, 4995).

*Notes*: *Phyloporus bellus* was originally described from Singapore (Massee 1914, Corner 1970), then reported from Malaysia, New Guinea, Korea, Japan, China, Philippines, and India (Massee 1914, Corner 1970, Bi *et al.* 1997, Zeng *et al.* 2013, Acharya *et al.* 2017). Illustrations and a full description of the species have been provided by Corner (1970) and Zeng *et al.* (2013).

***Phyloporus bogoriensis*** Höhn., Sitzungsber. Kaiserl. Akad. Wiss., Wien. Math.-Naturwiss. Cl., Abt. 1. 123: 89. 1914. MycoBank MB 183272.

*Known distribution*: Southern China (Hainan Province); Malaysia, Singapore, and Indonesia (Höhnelt 1914, Corner 1970, Neves *et al.* 2012, Wu *et al.* 2021).

*Material examined*: **China**, Hainan Province, Wuzhishan City, campus of Qiongzhou College, elev. 350 m, 30 Jul. 2010, N.K. Zeng, Zeng761 (FHMU459).

*Notes*: *Phyloporus bogoriensis* was originally described from Southeast Asia (Höhnelt 1914, Corner 1970); illustrations and a full description of the species have been provided by Corner (1970) and Wu *et al.* (2021).

***Phyloporus brunneiceps*** N.K. Zeng *et al.*, Fungal Diversity 58: 82. 2013. MycoBank MB 800146.

*Known distribution*: Southwestern China (Yunnan Province); Korea, Pakistan (Zeng *et al.* 2013, Lee *et al.* 2014, Naseer *et al.* 2017).

*Holotype*: KUN-HKAS56903 (China, Yunnan Province).

*Notes*: *Phyloporus brunneiceps* was originally described from Yunnan Province, southwestern China (Zeng *et al.* 2013), then reported from Korea and Pakistan (Lee *et al.* 2014, Naseer *et al.* 2017). Illustrations and a full description of the species have been provided by Zeng *et al.* (2013).

***Phyloporus castanopsidis*** M.A. Neves & Halling, Fungal Diversity 55: 112. 2012. MycoBank MB 563611.

*Known distribution*: Southern China (Hainan Province); Thailand (Neves *et al.* 2012, Wu *et al.* 2021).

*Holotype*: MFLU 08-1118 (Thailand, Chiang Mai Province).

*Materials examined*: **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 14 Aug. 2020, N.K. Zeng, Zeng4788, 4789 (FHMU5400, 5413).

*Notes*: *Phyloporus castanopsidis* was originally described from Thailand (Neves *et al.* 2012), and subsequently also reported from China (Wu *et al.* 2021). Illustrations and a full description of the

species have been provided by Neves *et al.* (2012) and Wu *et al.* (2021).

***Phylloporus grossus*** N.K. Zeng *et al.*, Mycol. Progr. 20: 1259. 2021. MycoBank MB 838777.

**Known distribution:** Central (Hunan Province) and southern China (Hainan Province) (Wu *et al.* 2021).

**Holotype:** FHMU3277 (China, Hunan Province).

**Materials examined:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 2 Jul. 2020, N.K. Zeng, Zeng4263, 4304 (FHMU4746, 4556); same location, 15 Aug. 2020, N.K. Zeng, Zeng4810, 4815, 4817 (FHMU5035, 5025, 4988).

**Notes:** *Phylloporus grossus* was originally described from central China (Hunan Province). Illustrations and a full description of the species have been provided by Wu *et al.* (2021).

***Phylloporus hainanensis*** N.K. Zeng, L.L. Wu, & Zhi Q. Liang, *sp. nov.* MycoBank MB 846898. Figs 49A, B, 50A, B, 51.

**Etymology:** *hainanensis* (Lat.), refers to Hainan Province, China, holotype locality.

**Diagnosis:** Differs from other species of *Phylloporus* by a pileus covered with pale brown to brown squamules, a white pileal context unchanging in colour when injured, a stipe covered with minute, reddish brown squamules, thin-walled cystidia, and a pileipellis composed of filamentous hyphae.

**Typus:** **China**, Hainan Province, Limushan of Hainan Tropical Rainforest National Park, elev. 750 m, 3 Jul. 2016, N.K. Zeng, Zeng2724 (**holotype** FHMU1718).

**Additional materials examined:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 2 Jul. 2020, N.K. Zeng, Zeng4272 (FHMU4723); Bawangling of Hainan Tropical Rainforest National Park, elev. 550 m, 3 Sep. 2020, N.K. Zeng, Zeng4984 (FHMU5550).

**Description:** *Basidiomata* very small to small-sized. *Pileus* 1.3–4.6 cm diam, convex to applanate; margin usually uplifted; surface dry, tomentose, then squamulose, pale brown (5B2) to brown (5B4); context about 0.5 cm thick in the centre of the pileus, white (1A1), unchanging in colour when injured. *Hymenophore* lamellate, decurrent. *Lamellae* up to 0.4 cm broad, subdistant, commonly anastomosing, yellow (1A6), changing bluish when injured, then back to yellow slowly; lamellulae common, attenuate, concolourous with lamellae. *Stipe* 3–4 × 0.3–0.9 cm, central, subcylindrical; surface dry, densely covered with minute squamules, squamules pale brown (5B2), brown (5B4) to reddish brown (6B6), sometimes yellow (2A6) at apex; upper part usually ribbed by the decurrent lines of the lamellae; context white (3A2), unchanging in colour when injured; annulus absent. *Basal mycelium* white (8A1). *Odour* not distinct.

*Basidia* 25–36 × 7–10.5 µm, clavate, thin-walled, 4-spored, yellowish in KOH; sterigmata 3–6 µm in length. *Basidiospores* [80/4/3] 8–12(–12.5) × (3.5–)4–4.5(–5) µm, Q = (1.77–)2–3(–3.14), Qm = 2.37 ± 0.35, cylindrical, slightly thick-walled (up to 0.5 µm), olive brown to yellowish brown in KOH, smooth under the light microscope, but with bacillate ornamentation under SEM. *Hymenophoral trama* phylloporoid, composed of slightly thick-walled (up to 1 µm) hyphae,

5–16 µm wide, colourless in KOH. *Cheilocystidia* 39–75 × 12–24 µm, abundant, subfusiform or fusiform, thin-walled, colourless or yellowish in KOH, no encrustations. *Pleurocystidia* 63–92 × 13–24 µm, abundant, fusiform or subfusiform, thin-walled, yellowish in KOH, no encrustations. *Pileipellis* a trichoderm 60–115 µm thick, composed of slightly interwoven, yellowish brown in KOH, 5–8 µm wide, thin- to slightly thick-walled (up to 0.5 µm) hyphae; terminal cells 25–30 × 5–7 µm, clavate or subcylindrical, with obtuse apex. *Pileal trama* composed of 4–15 µm wide, colourless to yellowish in KOH, slightly thick-walled (up to 0.5 µm) hyphae. *Stipitipellis* a trichoderm-like structure 45–70 µm thick, composed of thin- to slightly thick-walled (up to 0.5 µm) hyphae 2–8 µm wide, deep yellow to yellowish brown in KOH; terminal cells 15–60 × 4–8 µm, clavate or subcylindrical, with obtuse apex. *Stipe trama* composed of 5–17 µm wide, cylindrical, thin- to slightly thick-walled (up to 0.5 µm), colourless to yellowish in KOH, parallel hyphae. *Clamp connections* absent in all tissues.

**Habitat:** Solitary or gregarious on the ground in forests dominated by fagaceous trees.

**Known distribution:** Southern China (Hainan Province).

**Notes:** Morphologically, *P. hainanensis* is similar to Chinese *P. brunneiceps* and *P. maculatus*. However, *P. brunneiceps* has a yellow to yellowish brown stipe with yellowish basal mycelia (Zeng *et al.* 2013); *P. maculatus* has a yellowish to brownish yellow stipe, and hyphae in pileipellis wider (up to 25 µm) (Zeng *et al.* 2013). *Phylloporus hainanensis* is also morphologically similar to *P. phaeoxanthus* var. *simplex*, however, the latter has a larger basidioma (pileus up to 6.5 cm), lamellae unchanging in colour when injured, and it is distributed in Costa Rica (Neves & Halling 2010). Phylogenetically, *P. hainanensis* is closely related to *P. rubeolus*, *P. pelletieri* and *P. subbacillisporus* (Fig. 4). However, *P. rubeolus* has a larger, reddish brown pileus (2.4–7 cm), and a pileipellis composed of inflated hyphae (up to 25 µm) with longer and wider terminal cells (25–60 × 7–11 µm) (Zeng *et al.* 2013); *P. pelletieri*, originally described from Europe (Ladurner & Simonini 2003), has a pileus tinged with red, a yellowish pileal context, and slightly longer basidiospores measuring 10–15 × 3.5–5 µm (Taylor *et al.* 2002); *P. subbacillisporus* has a pileal context turning blue, then reddish when injured, a stipe tinged with orangish brown, and narrower basidiospores measuring 8.8–13.1 × 2.9–3.9 µm (Chuankid *et al.* 2019).

***Phylloporus imbricatus*** N.K. Zeng *et al.*, Fungal Diversity 58: 84. 2013. MycoBank MB 800147.

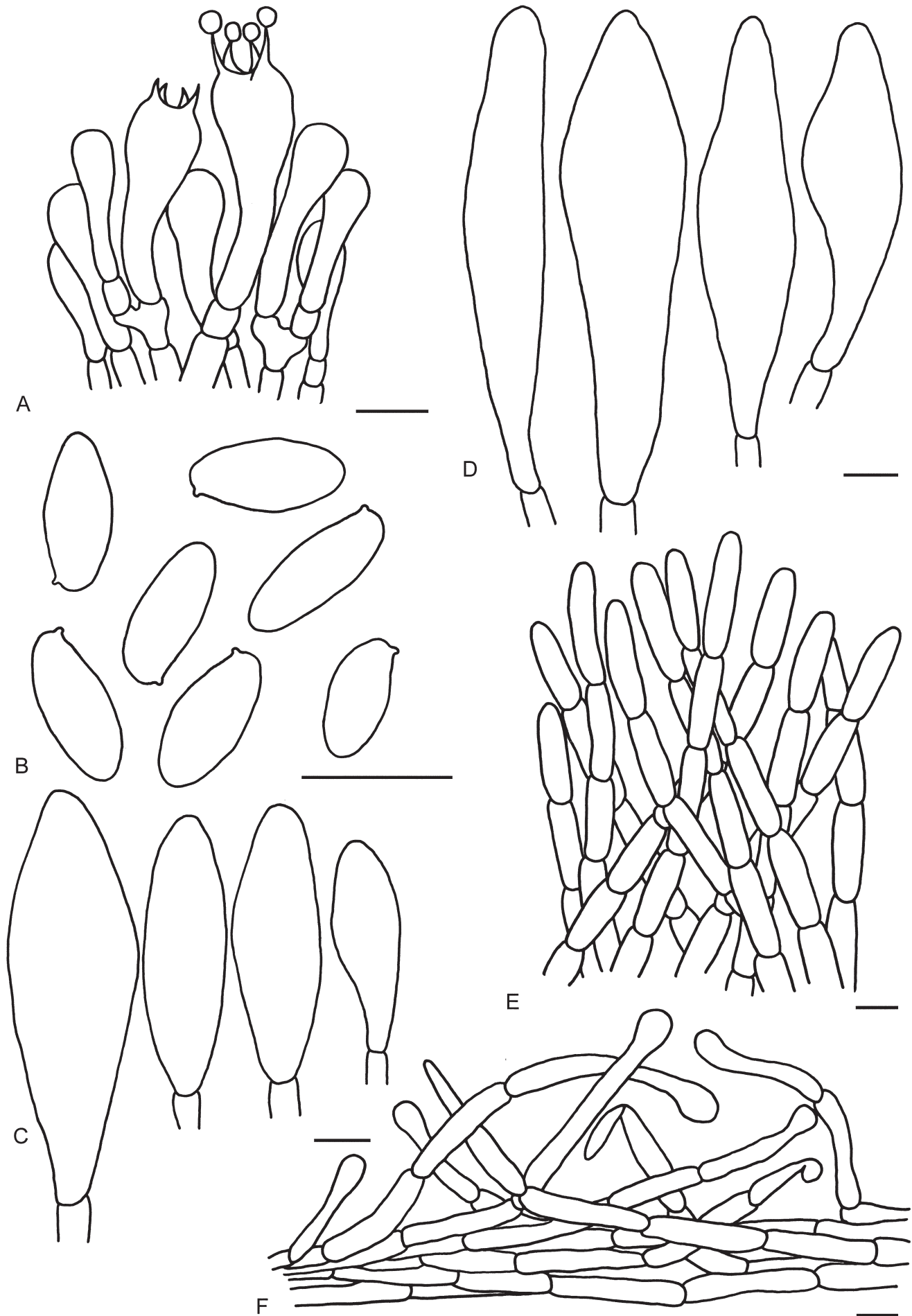
**Known distribution:** Southwestern China (Yunnan Province) (Wu *et al.* 2021).

**Holotype:** KUN-HKAS54647 (China, Yunnan Province).

**Notes:** *Phylloporus imbricatus* was originally described from Yunnan Province, southwestern China (Wu *et al.* 2021); illustrations and a full description of the species have been provided by Zeng *et al.* (2013).

***Phylloporus luxiensis*** M. Zang, Acta Microbiol. Sinica: 283. 1978. MycoBank MB 320295.

**Synonym:** *Phylloporus dimorphus* M.A. Neves & Halling, Fungal Diversity 55: 116. 2012.



**Fig. 51.** Microscopic features of *Phylloporus hainanensis* (holotype FHMU1718). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10 µm. Drawings by L.L. Wu.



**Known distribution:** Southwestern (Yunnan Province), southeastern (Fujian Province), central (Hunan Province), and southern China (Hainan Province); Thailand, Vietnam (Zang & Zeng 1978, Lee *et al.* 2020, Zeng *et al.* 2011, Wu *et al.* 2021, Neves *et al.* 2012).

**Holotype:** KUN-HKAS40150 (China, Yunnan Province).

**Material examined:** **China**, Yunnan Province, Nanhua County, Zixi Town, near Dafengyakou Bridge, elev. 2 013 m, 5 Aug. 2020, W.H. Zhang, Zhang367 (FHMU6088).

**Notes:** *Phylloporus luxiensis* was originally described from Yunnan Province, southwestern China (Zang & Zeng 1978); illustrations and a full description of the species have been provided by Zeng *et al.* (2011) and Wu *et al.* (2021). The species was called “Qiaomianbabajun” in Yunnan Province of southwestern China, which sold in the market for edibility. Our molecular data further confirmed that *P. dimorphus*, originally described from Thailand (Neves *et al.* 2012), is a synonym of *P. luxiensis* (Fig. 4), which was also noted by Wu *et al.* (2021).

***Phylloporus maculatus*** N.K. Zeng *et al.*, Fungal Diversity 58: 86. 2013. MycoBank MB 800148.

**Known distribution:** Southwestern China (Yunnan Province); India (Zeng *et al.* 2013, Dyutiparna *et al.* 2018).

**Holotype:** KUN-HKAS56683 (China, Yunnan Province).

**Notes:** *Phylloporus maculatus* was originally described from Yunnan Province, southwestern China (Zeng *et al.* 2013), then reported from India (Dyutiparna *et al.* 2018). Illustrations and a full description of the species have been provided by Zeng *et al.* (2013).

***Phylloporus microsquamus*** N.K. Zeng *et al.*, Mycol. Progr. 20: 1262. 2021. MycoBank MB 838778.

**Known distribution:** Southern (Hainan and Guangxi Provinces) and southwestern China (Yunnan Province) (Wu *et al.* 2021).

**Holotype:** FHMU1678 (China, Hainan Province).

**Notes:** *Phylloporus microsquamus* was originally described from Hainan Province, southern China (Wu *et al.* 2021). Illustrations and a full description of the species have been provided by Wu *et al.* (2021).

***Phylloporus nigrisquamus*** N.K. Zeng *et al.*, Mycol. Progr. 20: 1264. 2021. MycoBank MB 838779.

**Known distribution:** Southwestern China (Yunnan Province) (Wu *et al.* 2021).

**Holotype:** FHMU3271 (China, Yunnan Province).

**Notes:** *Phylloporus nigrisquamus* was originally described from Yunnan Province, southwestern China. Illustrations and a full description of the species have been provided by Wu *et al.* (2021).

***Phylloporus nigrobrunneus*** N.K. Zeng *et al.*, Mycol. Progr. 20: 1266. 2021. MycoBank MB 838780.

**Known distribution:** Southwestern China (Yunnan Province) (Wu *et al.* 2021).

**Holotype:** FHMU3268 (China, Yunnan Province).

**Notes:** *Phylloporus nigrobrunneus* was originally described from Yunnan Province, southwestern China (Wu *et al.* 2021). Illustrations and a full description of the species have been provided by Wu *et al.* (2021).

***Phylloporus pachycystidiatus*** N.K. Zeng, Zhu L. Yang & L.P. Tang, Fungal Diversity 58: 87. 2013. MycoBank MB 800149.

**Known distribution:** Southwestern China (Yunnan Province); Vietnam (Zeng *et al.* 2013, Pham & Morozova 2020).

**Holotype:** KUN-HKAS54540 (China, Yunnan Province).

**Notes:** *Phylloporus pachycystidiatus* was originally described from Yunnan Province, southwestern China (Zeng *et al.* 2013), then reported from Vietnam (Pham & Morozova 2020). Illustrations and a full description of the species have been provided by Zeng *et al.* (2013).

***Phylloporus parvisporus*** Corner, Nova Hedwigia 20: 811. 1971. MycoBank MB 320300.

**Known distribution:** Southern (Hainan Province), southeastern (Fujian Province), and southwestern China (Yunnan Province); Singapore (Bi *et al.* 1997, Zeng *et al.* 2013, Zeng & Jiang 2020).

**Material examined:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 800 m, 4 Jul. 2020, N.K. Zeng, Zeng4477 (FHMU3340).

**Notes:** *Phylloporus parvisporus* was originally described from Singapore (Corner *et al.* 1971), then reported from China (Bi *et al.* 1997, Zeng *et al.* 2013). Illustrations and a full description of the species have been provided by Corner *et al.* (1971) and Zeng *et al.* (2013).

***Phylloporus pruinus*** Kuan Zhao & N.K. Zeng, Phytotaxa 372: 217. 2018. MycoBank MB 827415.

**Known distribution:** Eastern (Anhui Province) and southwestern China (Yunnan Province) (Zhao *et al.* 2018).

**Holotype:** KUN-HKAS101929 (China, Anhui Province).

**Notes:** *Phylloporus pruinus* was originally described from Anhui Province, eastern China (Zhao *et al.* 2018). Illustrations and a full description of the species have been provided by Zhao *et al.* (2018).

***Phylloporus pusillus*** Raspé *et al.*, Mycol. Progr. 18: 605. 2019. MycoBank MB 827266. Figs 49C, D, 50C, D, 52.

**Description:** *Basidiomata* very small-sized. *Pileus* 1.5–1.9 cm diam, convex to applanate, centre slightly depressed; margin decurved; surface dry, tomentose, pale brown, brown to dark brown, usually covered with a thin layer of white pruina; context 0.1–0.3 cm thick in the centre of the pileus, yellowish, unchanging in colour when injured. *Hymenophore* lamellate, decurrent. *Lamellae* up to 0.2 cm

broad, subdistant, commonly anastomosing, yellow, unchanging in colour when injured; lamellulae common, attenuate, concolour with lamellae. *Stipe* 1.6–2.2 × 0.3–0.4 cm, central, subcylindrical; surface dry, densely covered with minute, pale brown squamules; context yellowish, unchanging in colour when injured; annulus absent. *Basal mycelium* white. *Odour* not distinct.

*Basidia* 34–41 × 8.5–10.5 µm, clavate, thin-walled, 4-spored, yellowish in KOH; sterigmata 3–5 µm in length. *Basidiospores* [40/2/2] 8.5–11(–11.5) × 4.5–5.5(–6.5) µm, Q = (1.62–)1.80–2.44, Qm = 2.06 ± 0.18, elongate to cylindrical, slightly thick-walled (up to 0.5 µm), olive brown to yellowish brown in KOH, smooth under the light microscope, but with bacillate ornamentation under SEM. *Hymenophoral trama* phylloporoid, composed of slightly thick-walled (up to 1 µm) hyphae, 5–17 µm wide, colourless in KOH. *Cheilocystidia* 50–74 × 10.5–16 µm, abundant, subfusiform or fusiform, colourless or yellowish in KOH, no encrustations. *Pleurocystidia* 54–87 × 10–14 µm, abundant, fusiform or subfusiform, colourless in KOH, no encrustations. *Pileipellis* a trichoderm 60–100 µm thick, composed of slightly interwoven, yellow in KOH, 6–15 µm wide, thin- to slightly thick-walled (up to 0.5 µm) hyphae; terminal cells 29–62 × 9–15 µm, clavate, subcylindrical or fusiform, with obtuse apex. *Pileal trama* composed of 6–16 µm wide, yellowish in KOH, slightly thick-walled (up to 0.5 µm) hyphae. *Stipitipellis* a trichoderm-like structure 55–125 µm thick, composed of thin- to slightly thick-walled (up to 0.5 µm) hyphae 5–15 µm wide, yellowish brown in KOH; terminal cells 33–70 × 8.5–15 µm, clavate, subcylindrical or fusiform, with obtuse apex. *Stipe trama* composed of longitudinally arranged hyphae 5–19 µm wide, cylindrical, thin- to slightly thick-walled (up to 0.5 µm), yellowish in KOH. *Clamp connections* absent in all tissues.

*Habitat*: Solitary to gregarious on the ground in forests dominated by fagaceous trees.

*Known distribution*: Southwestern (Yunnan Province) and southern China (Hainan Province); Thailand (Chuankid *et al.* 2019).

*Holotype*: CMUB, Raspé, OR1310 (Thailand, Chiang Mai Province).

*Materials examined*: **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 3 Jul. 2020, N.K. Zeng, Zeng4466 (FHMU3361); Wuzhishan of Hainan Tropical Rainforest National Park, elev. 700 m, 12 Aug. 2020, N.K. Zeng, Zeng4610 (FHMU5010).

*Notes*: *Phylloporus pusillus* was firstly described from Thailand (Chuankid *et al.* 2019), then reported from China (Zeng & Jiang 2020). The species is characterised by a very small-sized basidioma, a pale brown, brown to dark brown pileus usually covered with a thin layer of white pruina, hymenophore and context unchanging in colour when injured, and a pileipellis composed of hyphae usually with inflated terminal cells.

***Phylloporus rubeolus*** N.K. Zeng *et al.*, Fungal Diversity 58: 91. 2013. MycoBank MB 800150.

*Known distribution*: Southwestern China (Yunnan Province) (Zeng *et al.* 2013).

*Holotype*: KUN-HKAS52573 (China, Yunnan Province).

*Notes*: *Phylloporus rubeolus* was originally described from Yunnan Province, southwestern China (Zeng *et al.* 2013). Illustrations and

a full description of the species have been provided by Zeng *et al.* (2013).

***Phylloporus rubiginosus*** M.A. Neves & Halling, Fungal Diversity 55: 118. 2012. MycoBank MB 563625.

*Known distribution*: Southwestern (Yunnan Province), southeastern (Fujian Province), and southern China (Hainan Province); Vietnam (Ye *et al.* 2014, Zhang *et al.* 2019b, Pham & Morozova 2020).

*Holotype*: MFLU 08–1110 (Thailand, Chiang Mai Province).

*Materials examined*: **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 2 Jul. 2020, N.K. Zeng, Zeng4287, 4304 (FHMU4746, 4556); same location, 4 Sep. 2020, N.K. Zeng, Zeng4993, 5009 (FHMU4800, 4791); Wanning City, Shimei Bay, elev. 5 m, 28 August 2020, N.K. Zeng, Zeng4828, 4833, 4834, 4836 (FHMU5377, 5378); same location, 15 Aug. 2020, N.K. Zeng, Zeng4810, 4815, 4817 (FHMU5035, 5025, 4988).

*Notes*: *Phylloporus rubiginosus* was originally described from Thailand (Neves *et al.* 2012), and subsequently reported from China and Vietnam (Ye *et al.* 2014, Zhang *et al.* 2019b, Pham & Morozova 2020). Illustrations and a full description of the species have been provided by Neves *et al.* (2012) and Zhang *et al.* (2019b).

***Phylloporus rubrosquamosus*** N.K. Zeng *et al.*, Fungal Diversity 58: 92. 2013. MycoBank MB 800151.

*Known distribution*: Southwestern China (Yunnan Province) (Zeng *et al.* 2013).

*Holotype*: KUN-HKAS54559 (China, Yunnan Province).

*Notes*: *Phylloporus rubrosquamosus* was originally described from Yunnan Province, southwestern China (Zeng *et al.* 2013). Illustrations and a full description of the species have been provided by Zeng *et al.* (2013).

***Phylloporus rufescens*** Corner, Nova Hedwigia 20: 814. 1971. MycoBank MB 320304.

*Known distribution*: Southern China (Hainan Province); Singapore (Corner *et al.* 1971, Zeng *et al.* 2013).

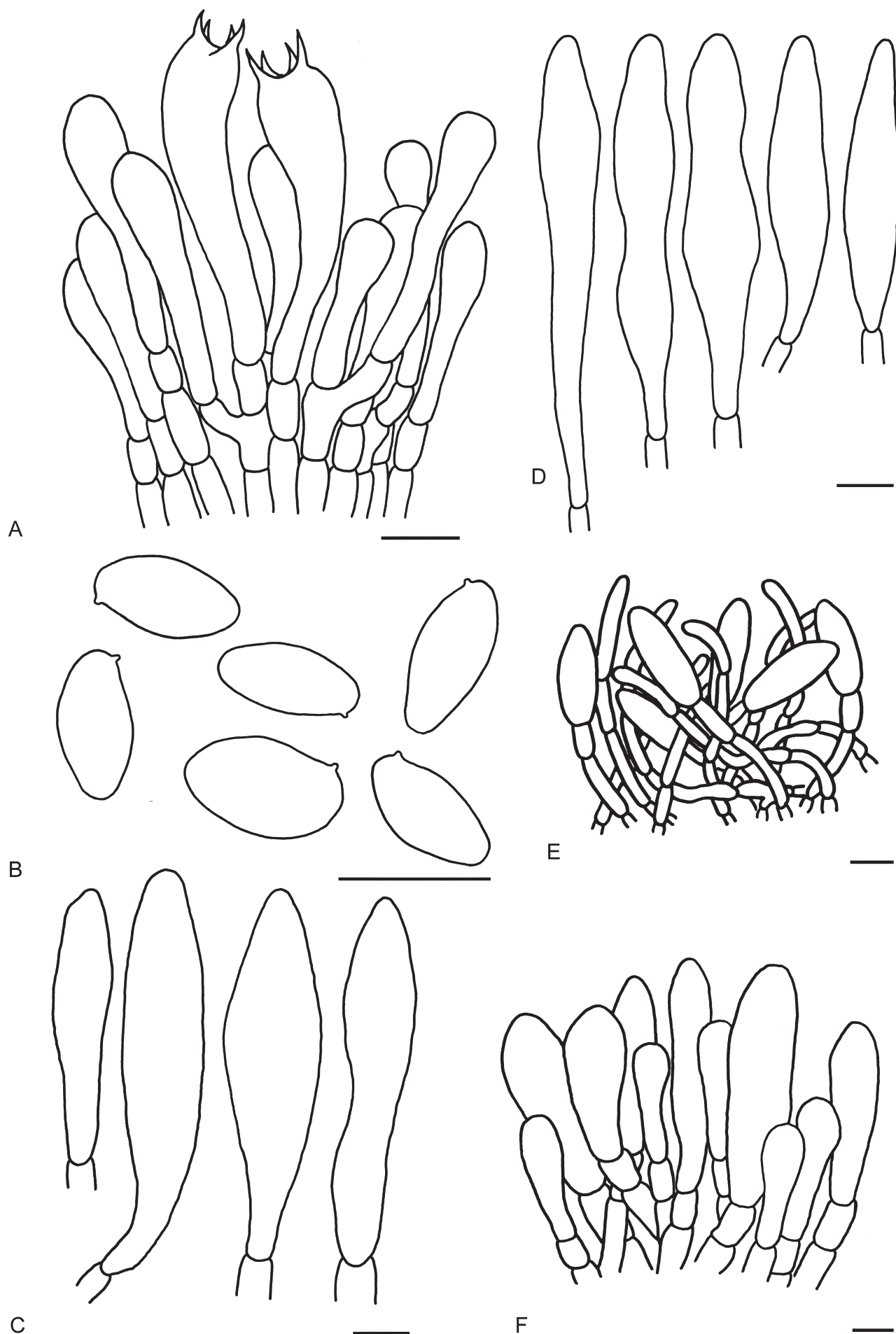
*Material examined*: **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 25 Apr. 2019, N.K. Zeng, Zeng4033 (FHMU3290).

*Notes*: *Phylloporus rufescens* was originally described from Singapore (Corner *et al.* 1971), then reported from China (Zeng *et al.* 2013). Illustrations and a full description of the species have been provided by Corner *et al.* (1971) and Zeng *et al.* (2013).

***Phylloporus subbacillisporus*** Raspé *et al.*, Mycol. Progr. 18: 608. 2019. MycoBank MB 827267.

*Known distribution*: Southwestern (Yunnan Province), eastern China (Anhui Province); Thailand (Chuankid *et al.* 2019, Wu *et al.* 2021).

*Holotype*: HMAS279879 (China, Yunnan Province).



**Fig. 52.** Microscopic features of *Phylloporus pusillus* (FHMU5010). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10  $\mu$ m. Drawings by L.L. Wu.



**Material examined:** China, Anhui Province, Jinzhai County, Roadside from Mazongling Tree Farm to Tiantan Village, elev. 955 m, 23 Jul. 2017, Y.J. Hao, Hao1553 (FHMU3293).

**Notes:** *Phylloporus subbacillisporus* was originally described from Yunnan Province, southwestern China (Chuankid *et al.* 2019). In the present study, it was also found to be distributed in Anhui Provinces of eastern China. Illustrations and a full description of the species have been provided by Chuankid *et al.* (2019).

***Phylloporus subrubeolus*** Chuankid *et al.*, Mycol. Progr. 18: 609. 2019. MycoBank MB 827268.

**Known distribution:** Southern (Hainan and Guangdong Provinces) and central China (Hunan Province); Thailand (Chuankid *et al.* 2019, Wu *et al.* 2021).

**Holotype:** MFLU 16–2229 (Thailand, Chiang Mai Province).

**Material examined:** China, Hainan Province, Jianfengling of Hainan Tropical Rainforest National Park, elev. 850 m, 10 Aug. 2020, N.K. Zeng, Zeng4588 (FHMU4891).

**Notes:** *Phylloporus subrubeolus* was originally described from Thailand (Chuankid *et al.* 2019), and subsequently reported from China (Wu *et al.* 2021). Illustrations and a full description of the species have been provided by Chuankid *et al.* (2019) and Wu *et al.* (2021).

***Phylloporus tenuissimus*** N.K. Zeng *et al.*, Mycol. Progr. 20: 1269. 2021. MycoBank MB 838781.

**Known distribution:** Southern China (Hainan Province) (Wu *et al.* 2021).

**Holotype:** FHMU2964 (China, Hainan Province).

**Notes:** *Phylloporus tenuissimus* was originally described from Hainan Province, southern China (Wu *et al.* 2021). Illustrations and a full description of the species have been provided by Wu *et al.* (2021).

***Phylloporus yunnanensis*** N.K. Zeng *et al.*, Fungal Diversity 58: 95. 2013. MycoBank MB 800152.

**Known distribution:** Southwestern China (Yunnan Province); India (Zeng *et al.* 2013, Dyutiparna *et al.* 2018).

**Holotype:** KUN-HKAS56999 (China, Yunnan Province).

**Notes:** *Phylloporus yunnanensis* was originally described from Yunnan Province, southwestern China (Zeng *et al.* 2013), then reported from India (Dyutiparna *et al.* 2018). Illustrations and a full description of the species have been provided by Zeng *et al.* (2013).

## Key to the accepted *Phylloporus* species from China

- 1a. Pileal surface brown, dark brown or olivaceous, without reddish tinge when mature ..... 2
- 1b. Pileal surface reddish to reddish brown ..... 14
- 2a. Pileal surface tinged with olivaceous, context pale brownish fuliginous ..... *P. parvisporus*
- 2b. Pileal surface brown, dark brown, context cream-coloured, yellowish or yellowish white ..... 3
- 3a. Hymenophore unchanging in colour when injured ..... 4
- 3b. Hymenophore turning blue when injured ..... 8
- 4a. Cystidia moderately thick-walled (up to 2 µm) ..... *P. grossus*
- 4b. Cystidia thin- to slightly thick-walled (up to 1 µm) ..... 5
- 5a. Pileal surface covered with a thin layer of white pruina ..... *P. pusillus*
- 5b. Pileal surface without a pruina ..... 6
- 6a. Pileal surface covered with squamules, cystidia longer (up to 175 µm) ..... *P. nigrisquamis*
- 6b. Pileal surface subtomentose, cystidia shorter (up to 93 µm) ..... 7
- 7a. Basidioma comparatively small (pileus 1.5– 2 cm diam), basidiospores narrower (up to 4.5 µm), hyphae in pileipellis 9–18 µm wide ..... *P. nigrobrunneus*
- 7b. Basidioma comparatively large (pileus up to 9.5 cm diam), basidiospores wider (up to 5.5 µm), hyphae in pileipellis 5–9 µm wide ..... *P. luxiensis*
- 8a. Context changing bluish or reddish when injured ..... 9
- 8b. Context unchanging in colour when injured ..... 11
- 9a. Context changing reddish quickly, then blackening when injured ..... *P. bogoriensis*
- 9b. Context changing bluish when injured ..... 10
- 10a. Pileal context about 0.5 cm in thickness, basidiospores 10–14.5 × 4–5.5 µm, pleurocystidia 89–115 × 14–17 µm .... *P. castanopsidis*
- 10b. Pileal context about 0.2 cm in thickness, basidiospores 10–12 × 4–5 µm, pleurocystidia 56–89 × 10–20 µm ..... *P. tenuissimus*

11a.	Pleurocystidia moderately thick-walled (1–2 µm), basidiospores wider (up to 5.5 µm) .....	<i>P. alboinfusatus</i>
11b.	Pleurocystidia thin- to slightly thick-walled (up to 1 µm), basidiospores narrower (up to 4.5 µm) .....	12
12a.	Hyphae in pileipellis wider (up to 25 µm) .....	<i>P. maculatus</i>
12b.	Hyphae in pileipellis narrower (up to 11 µm) .....	13
13a.	Stipe surface densely covered with reddish-brown squamules .....	<i>P. hainanensis</i>
13b.	Stipe surface tomentose, yellow to yellowish-brown .....	<i>P. brunneiceps</i>
14a.	Cystidia thick-walled (> 1 µm) .....	15
14b.	Cystidia thin- to slightly thick-walled (< 1 µm) .....	16
15a.	Pileal surface yellowish-brown to reddish-brown, context unchanging in colour but hymenophore turning bluish when injured .....	<i>P. pachycystidiatus</i>
15b.	Pileal surface brownish red to reddish, hymenophore and context turning bluish-olivaceous, then turning red and finally blackening when injured .....	<i>P. rubiginosus</i>
16a.	Lamellae crowded, blue-red-black colour change of context .....	<i>P. rufescens</i>
16b.	Lamellae subdistant, context turning bluish or unchanging in colour when injured .....	17
17a.	Hyphae uninflated in the pileipellis .....	18
17b.	Hyphae more or less inflated in the pileipellis .....	19
18a.	Basidiospores longer (11–12.5 × 4.5–5 µm) .....	<i>P. rubrosquamosus</i>
18b.	Basidiospores shorter (8–11 × 4–5.5 µm) .....	<i>P. microsquamus</i>
19a.	Basidiospores narrower (< 4 µm) .....	<i>P. subbacillisporus</i>
19b.	Basidiospores wider (≥ 4 µm) .....	20
20a.	Basidiospores shorter (< 8 µm) .....	<i>P. subrubeolus</i>
20b.	Basidiospores longer (≥ 8 µm) .....	21
21a.	Basidiomata smaller (pileus 2–3 cm diam), pileus with a thin, white pruina .....	<i>P. pruinatus</i>
21b.	Basidiomata larger (pileus up to 11 cm diam), pileus without a pruina .....	22
22a.	Distributed in temperate China, associated with trees of <i>Abies</i> and/or <i>Picea</i> .....	<i>P. imbricatus</i>
22b.	Distributed in subtropical-tropical China, associated with trees of <i>Fagaceae</i> .....	23
23a.	Terminal cells of pileipellis with acute apex .....	<i>P. rubeolus</i>
23b.	Terminal cells of pileipellis with obtuse apex .....	24
24a.	Basidiospores wider (up to 5 µm) .....	<i>P. bellus</i>
24b.	Basidiospores narrower (up to 4.5 µm) .....	<i>P. yunnanensis</i>

***Pulchroboletus*** Gelardi, Vizzini & Simonini, Mycologia 106: 1176. 2014.

*Pulchroboletus*, typified by *P. roseoalbidus*, is characterised by its pale pink, cream pinkish to whitish pink or rarely blood red pileus, smooth to densely punctuate, or rarely coarse reticulate stipe, sometimes with pseudo-annulus at the upper or middle part, and pinkish purple context of the pileus (Gelardi *et al.* 2014). The genus was reported from Europe and North America in previous studies (Gelardi *et al.* 2014, Farid *et al.* 2017, Crous *et al.* 2019). The discovery of new species of *Pulchroboletus* in China in the present study indicates that the genus has a much wider geographical distribution range.

***Pulchroboletus erubescens*** N.K. Zeng, Chang Xu & Zhi Q. Liang, *sp. nov.* MycoBank MB 846899. Figs 53–55.

*Etymology*: *erubescens* (Lat.), refers to the pink pileus.

*Diagnosis*: Differs from other species of *Pulchroboletus* by a pink pileus, a yellowish white stipe densely covered with pink squamules, and small basidiospores.

*Typus*: **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 2 Jul. 2020, N.K. Zeng, Zeng4274 (**holotype** FHMU4543).

*Additional materials examined*: **China**, Hainan Province, Yinggeling of Hainan Tropical Rainforest National Park, elev. 650 m, 2 Jul. 2020, N.K. Zeng, Zeng4302 (FHMU4710); same location, elev. 550 m, 4 Jun. 2017, S. Jiang, Jian52 (FHMU7592).

*Description*: *Basidiomata* large-sized. *Pileus* 10.5–11 cm diam, convex to applanate, margin uneven; surface dry, subtomentose, wrinkle, pink (7A2); context 1–2 cm thickness in the centre of the pileus, yellowish (1A2), unchanging in colour when injured. *Hymenophore* poroid, slightly depressed around apex of stipe; pores angular, about 0.3 mm diam, yellow (1A3), changing blue



Fig. 53. Basidiomata of *Pulchroboletus erubescens* A, C. FHMU4710. B. holotype FHMU4543. Photos by N.K. Zeng.

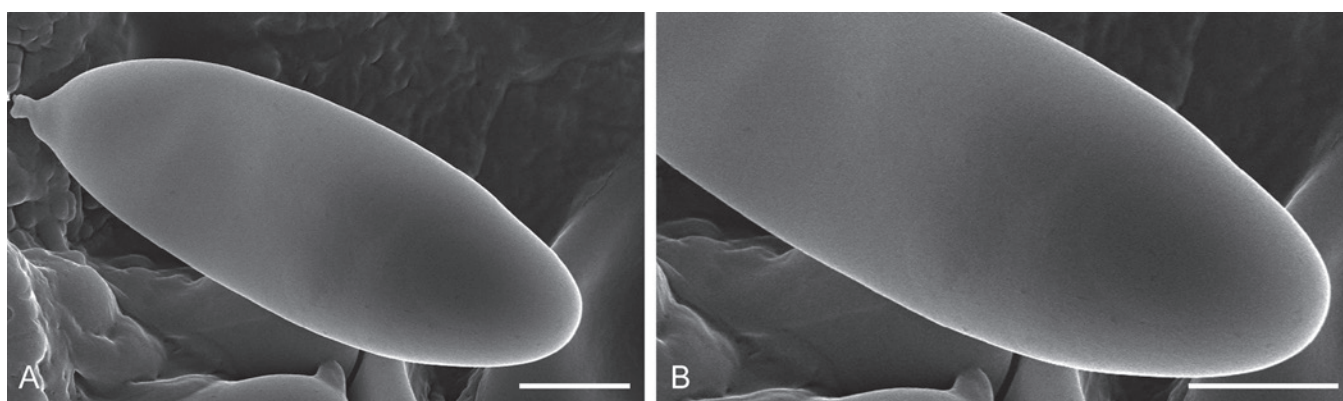


Fig. 54. Basidiospores of *Pulchroboletus erubescens* from herbarium materials under SEM (holotype FHMU4543). Photos by C. Xu.

when injured; tubes 0.6–0.8 cm in length, yellowish, changing blue when injured. *Stipe* 7.5–8 × 1–2.2 cm, central, solid, subcylindric; surface yellowish white, densely covered with pink (7A2) squamules; context yellowish (1A2), unchanging in colour when injured; basal mycelium white (2A1). *Odour* indistinct.

*Basidia* 20–38 × 9–11 µm, clavate, thin-walled, 4-spored, colourless in KOH; sterigmata 3–5 µm long. *Basidiospores* [60/3/3] 9–11.5 × 4–5.5 µm, Q = 1.80–2.50, Qm = 2.12 ± 0.16, subfusiform, slightly thick-walled (up to 1 µm), yellowish brown in KOH, smooth. *Hymenophoral trama* composed of thin- to slightly thick-walled (up to 1 µm) hyphae, 5–8 µm wide, colourless in KOH. *Cheilocystidia* 35–40 × 7–11 µm, subfusiform or fusiform, thin- to slightly thick-walled (up to 1 µm), colourless in KOH. *Pleurocystidia* 43–60 × 6–11 µm, clavate, subfusiform or fusiform, thin- to slightly thick-walled (up to 1 µm), colourless in KOH. *Pileipellis* a trichoderm 113–137 µm thick, composed of hyphae thin- to slightly thick-walled (up to 1 µm), colourless in KOH, 4–13 µm in width; terminal cell 20–40 × 4–7 µm, clavate or subcylindrical, with obtuse apex. *Pileal trama* made up of hyphae 5–13 µm diam, thin-walled, dark yellowish brown in KOH. *Stipitipellis* a trichoderm-like structure 50–180 µm thick, composed of thin- to slightly thick-walled (up to 1 µm), 7–16 µm wide, colourless in KOH, emergent hyphae with clavate, subfusiform or subcylindrical terminal cells (20–49 × 4–10 µm). *Stipe trama* composed of cylindrical, brownish yellow in KOH, thin- to slightly thick-walled (up to 0.6 µm) hyphae 3–12 µm wide. *Clamp connections* absent in all tissues.

*Habitat*: Scattered on the ground in forests dominated by fagaceous trees.

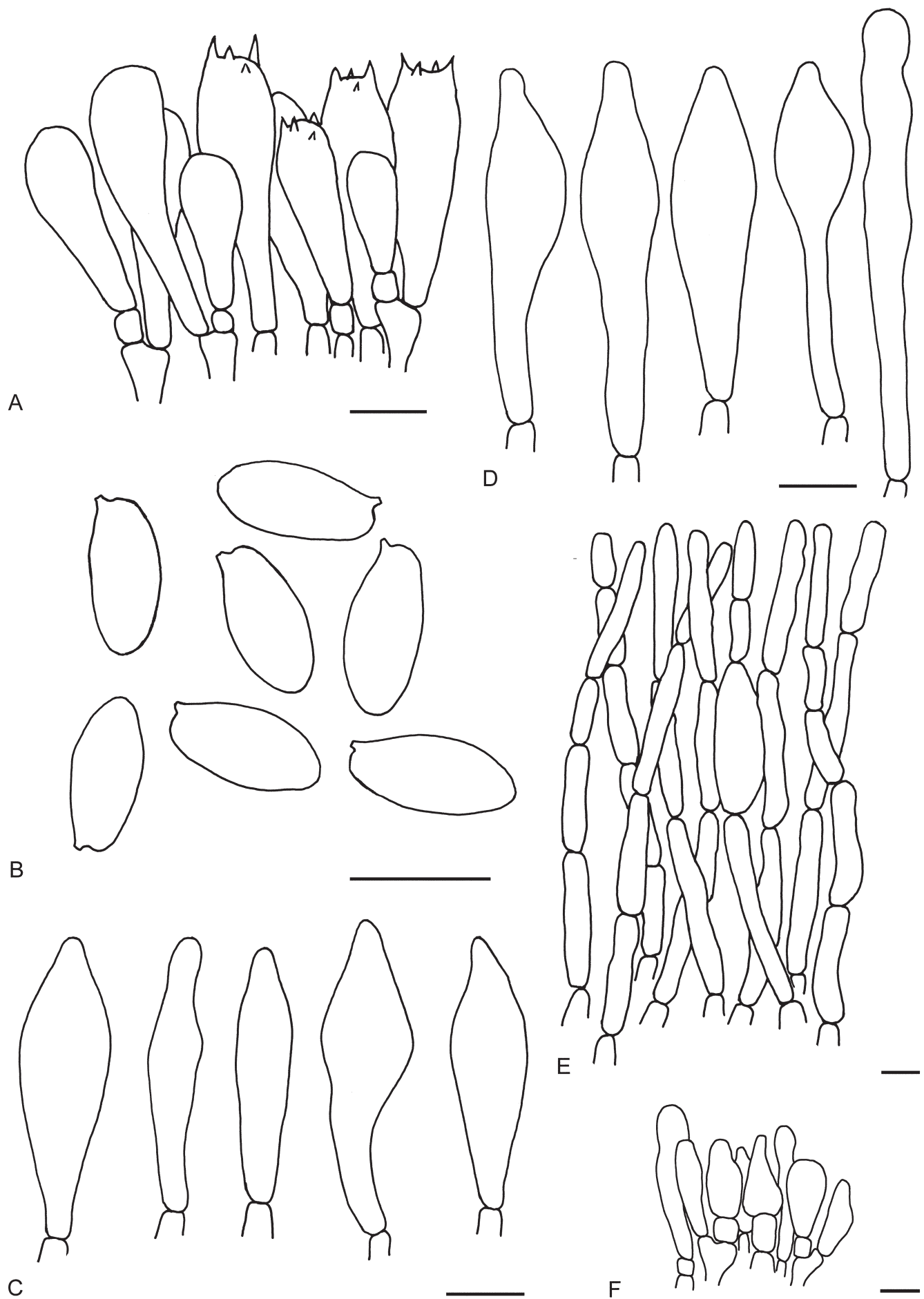
*Known distribution*: Southern China (Hainan Province).

*Notes*: Morphologically, *Pul. erubescens* is similar to *Pul. roseoalbidus*, *Pul. rubricitrinus*, and *Pul. sclerotiorum*. However, *Pul. roseoalbidus* has a stipe with a prominent but narrow granular pseudo-annular zone, larger basidiospores measuring 13.5–16 × 6.5–7.5 µm, and it is distributed in Europe (Gelardi *et al.* 2014); *Pul. rubricitrinus* has a larger basidioma (pileus up to 16 cm diam), a pink, testaceous, blood red pileus, larger basidiospores measuring 13.8–15.9 × 4.6–5.8 µm, and it is distributed in North America (Farid *et al.* 2017); *Pul. sclerotiorum* has a rose red to purple red pileus, a stipe covered with reddish brown spots, large basidiospores measuring 12–18 × 4–6 µm, and it is distributed in North America (Crous *et al.* 2019). Phylogenetically, species closely related to *Pul. erubescens* was not detected from our current data (Fig. 5).

*Xerocomus* Qué. Fl. Vosges, Champ.: 477. 1887.

*Xerocomus*, typified by *X. subtomentosus*, is characterised by tomentose and siccous pileus, normal long tubes with relatively large pores (1–3 mm diam), context becoming bluish to blue when injured, trichodermium pileipellis, and bacillately warted, sometimes smooth basidiospores under SEM (Cokers *et al.* 1974, Wu *et al.* 2016). Besides two new species described in the present study, eight species have been confirmed to distribute in China (Wu *et al.* 2016).





**Fig. 55.** Microscopic features of *Pulchroboletus erubescens* (holotype FHMU4543). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10  $\mu$ m. Drawings by Y.Y. Yang.



Fig. 56. Basidiomata of *Xerocomus* species. A–D. *X. albotomentosus* (A. FHMU2825; B. FHMU2232; C, D. holotype FHMU2974). E–G. *X. fuscatus* (E. FHMU4940. F. FHMU4967. G. holotype FHMU4922). H, I. *X. rugosellus* (H. FHMU6011; I. FHMU6029). A–G photos by N.K. Zeng; H, I photos by H.Y. Huang.

***Xerocomus albotomentosus*** N.K. Zeng, H.J. Xie, Chang Xu & Zhi Q. Liang, *sp. nov.* MycoBank MB 846900. Figs 56A–D, 58A, B, 59.

**Etymology:** *albotomentosus* (Lat.), refers to the white villous mycelia at the stipe base.

**Diagnosis:** Differs from other species of *Xerocomus* by a stipe covered with minute, yellowish brown to pale yellowish brown squamules, a stipe base with obvious white villous mycelia, and a context unchanging in colour when injured.

**Typus:** **China**, Hainan Province, Jianfengling of Hainan Tropical Rainforest National Park, elev. 850 m, 10 Aug. 2020, N.K. Zeng, Zeng3395 (holotype FHMU2974).

**Additional materials examined:** **China**, Fujian Province, Yongan City, Tianbaoyuan National Natural Reserve, elev. 350 m, 17 Aug. 2017, N.K. Zeng, Zeng3271 (FHMU2232); Yunnan Province, Jinping County,

Fenshuiling National Nature Reserve, elev. 1 800 m, 13 Jul. 2018, N.K. Zeng, Zeng3611 (FHMU2825); Guangdong Province, Renhua County, Danxiashan National Natural Reserve, elev. 360 m, 5 Jun. 2019, N.K. Zeng, Zeng4104 (FHMU3794).

**Description:** *Basidiomata* small to medium-sized. *Pileus* 3–6 cm diam, convex to applanate, slightly depressed in the centre when old, margin decurved; surface dry or sometimes slightly sticky, tomentose, yellowish brown (2B5), brown (2B8) to dark brown (7D5); context 0.3–1.1 cm thick in the centre of the pileus, white (7A2), unchanging in colour when injured. *Hymenophore* poroid, depressed around apex of stipe; pores compound, angular, 0.5–1 mm diam, yellow (2A7), turning bluish when injured; tubes 0.5–0.9 cm in length, yellowish (2A5), slowly turning bluish in colour when injured. *Stipe* 3–5.8 × 0.5–0.6 cm, central, subcylindric; surface dry, densely covered with minute, pale yellowish brown squamules; context white (7A1), unchanging in colour when injured; annulus absent; basal mycelium white (1A1). *Odour* indistinct.





Fig. 57. Basidiomata of *Xerocomus* species. A–C. *X. subparvus* (A. FHMU1630; B. FHMU2241; C. FHMU3344). D–F. *X. yunnanensis* (D. FHMU3071; E, F. FHMU3059). Photos by N.K. Zeng.

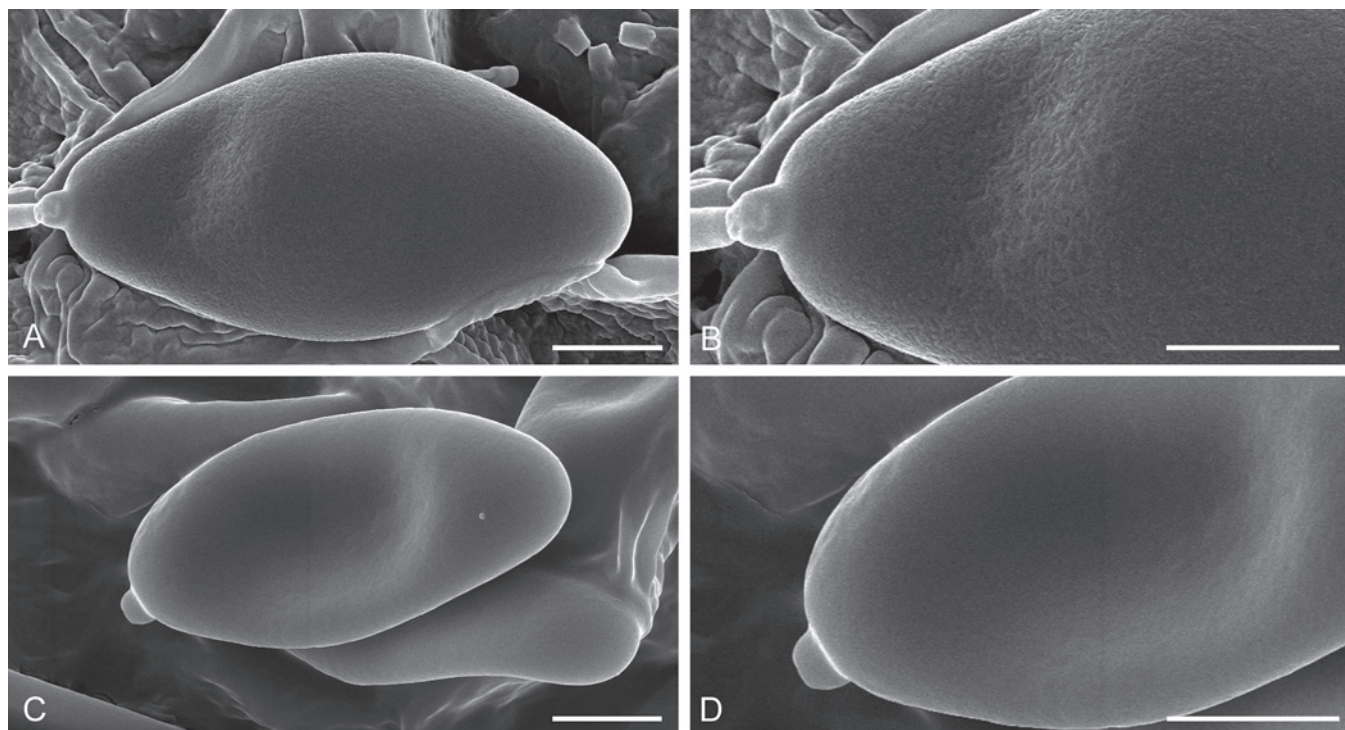


Fig. 58. Basidiospores of *Xerocomus* species from herbarium materials under SEM. A, B. *X. albotomentosus* (FHMU2825). C, D. *X. fuscatus* (holotype FHMU4922). Photos by C. Xu.

*Basidia*  $22\text{--}34 \times 10\text{--}12\ \mu\text{m}$ , clavate, thin-walled, 4-spored, colourless in KOH; sterigmata  $2\text{--}4\ \mu\text{m}$  long. *Basidiospores*  $[100/5/4]\ 8\text{--}12(\text{--}13) \times 4\text{--}5.5(\text{--}6)\ \mu\text{m}$ ,  $Q = (1.5\text{--})1.6\text{--}2.7(\text{--}3)$ ,  $Q_m = 2.12 \pm 0.31$ , subfusiform, slightly thick-walled (up to  $0.5\ \mu\text{m}$ ),

yellowish brown in KOH, smooth. *Hymenophoral trama* composed of thin- to slightly thick-walled (up to  $0.5\ \mu\text{m}$ ) hyphae,  $6\text{--}14\ \mu\text{m}$  wide, colourless in KOH. *Cheilocystidia*  $13\text{--}50 \times 6\text{--}13\ \mu\text{m}$ , subfusiform or fusiform, thin-walled, colourless in KOH. *Pleurocystidia*  $40\text{--}63 \times$



11–18 µm, subfusiform or fusiform, thin-walled, colourless in KOH. *Pileipellis* a trichoderm 200–300 µm thick, composed of hyphae thin- to slightly thick-walled (up to 1 µm), colourless to light yellow in KOH, 4–19 µm in width; terminal cell 20–77 × 4–11.5 µm, clavate, subcylindrical or subfusiform, with obtuse apex. *Pileal trama* made up of hyphae 3–21 µm diam, slightly thick-walled (up to 1 µm), light yellow in KOH. *Stipitipellis* a trichoderm-like structure 60–100 µm thick, composed of thin- to slightly thick-walled (up to 1 µm), 4–13 µm wide, light yellow in KOH, emergent hyphae with subfusiform, subcylindrical or clavate terminal cells (16–36 × 4–13 µm). *Stipe trama* composed of cylindrical, light yellow in KOH, slightly thick-walled (up to 1 µm), parallel hyphae 4–17 µm wide. *Clamp connections* absent in all tissues.

**Habitat:** Solitary or caespitose on the ground in forests dominated by fagaceous trees.

**Known distribution:** Southwestern (Yunnan Province), southeastern (Fujian Province), and southern China (Hainan Province).

**Notes:** In one previous study, *X. albotomentosus* was misidentified as *X. nigromaculatus* (Thongkantha *et al.* 2021), originally described from Japan (Hongo 1966). However, *X. nigromaculatus* is easily recognised by the blackish staining of pileus and stipe, the context becoming first bluish then reddish, and smaller basidiospores measuring 7.5–10.5 × 3.5–4 µm (Hongo 1966). *Xerocomus albotomentosus* is also morphologically similar to *X. illudens*, *X. subtomentosus*, and *X. tenax*. However, *X. illudens*, originally described from North America, has a pileus tinged with pinkish, a stipe usually marked by coarse ridges and anastomosing lines, longer but narrower basidiospores measuring 10–14 × 4–5 µm, and hyphae in pileipellis uninflated (up to 10 µm) (Singer 1945c, Smith & Thiers 1971); *X. subtomentosus* has a larger basidioma (pileus up to 15 cm diam), larger basidiospores measuring 9.8–14.8 × 3.9–6 µm, and it is distributed in temperate region (Hills 2008); *X. tenax* has a larger basidioma (pileus up to 10 cm diam), a conspicuously reticulate stipe, hyphae in pileipellis uninflated (up to 10 µm), and it is distributed in North America (Smith & Thiers 1971, Halling *et al.* 2015). Phylogenetically, *X. albotomentosus* is closely related to *X. fraternus* (Fig. 6), however, the latter has a stipe with fine longitudinal striations, stipe context turning pale red brown when injured, and narrower hyphae in pileipellis (up to 14 µm) (Wu *et al.* 2016).

***Xerocomus fraternus*** Xue T. Zhu & Zhu L. Yang, Fungal Diversity 81: 173. 2016. MycoBank MB 818502.

**Known distribution:** Southwestern China (Yunnan Province) (Wu *et al.* 2016).

**Holotype:** KUN-HKAS55328 (China, Yunnan Province).

**Notes:** *Xerocomus fraternus* was originally described from Yunnan Province, southwestern China (Wu *et al.* 2016). Illustrations and a full description of the species have been provided by Wu *et al.* (2016).

***Xerocomus fulvipes*** Xue T. Zhu & Zhu L. Yang, Fungal Diversity 81: 174. 2016. MycoBank MB 818503.

**Known distribution:** Southwestern China (Yunnan Province) (Wu *et al.* 2016).

**Holotype:** KUN-HKAS68246 (China, Yunnan Province).

**Notes:** *Xerocomus fulvipes* was originally described from Yunnan Province, southwestern China (Wu *et al.* 2016); illustrations and a full description of the species have been provided by Wu *et al.* (2016).

***Xerocomus fuscatus*** N.K. Zeng, H.J. Xie, Chang Xu & Zhi Q. Liang, **sp. nov.** MycoBank MB 846901. Figs 56E–G, 58C, D, 60.

**Etymology:** *fuscatus* (Lat.), refers to the dark brown pileus.

**Diagnosis:** Differs from other species of *Xerocomus* by a small to medium-sized basidioma, a yellowish brown, brown to dark brown pileus, and smooth basidiospores without bacillate surface ornamentation under SEM.

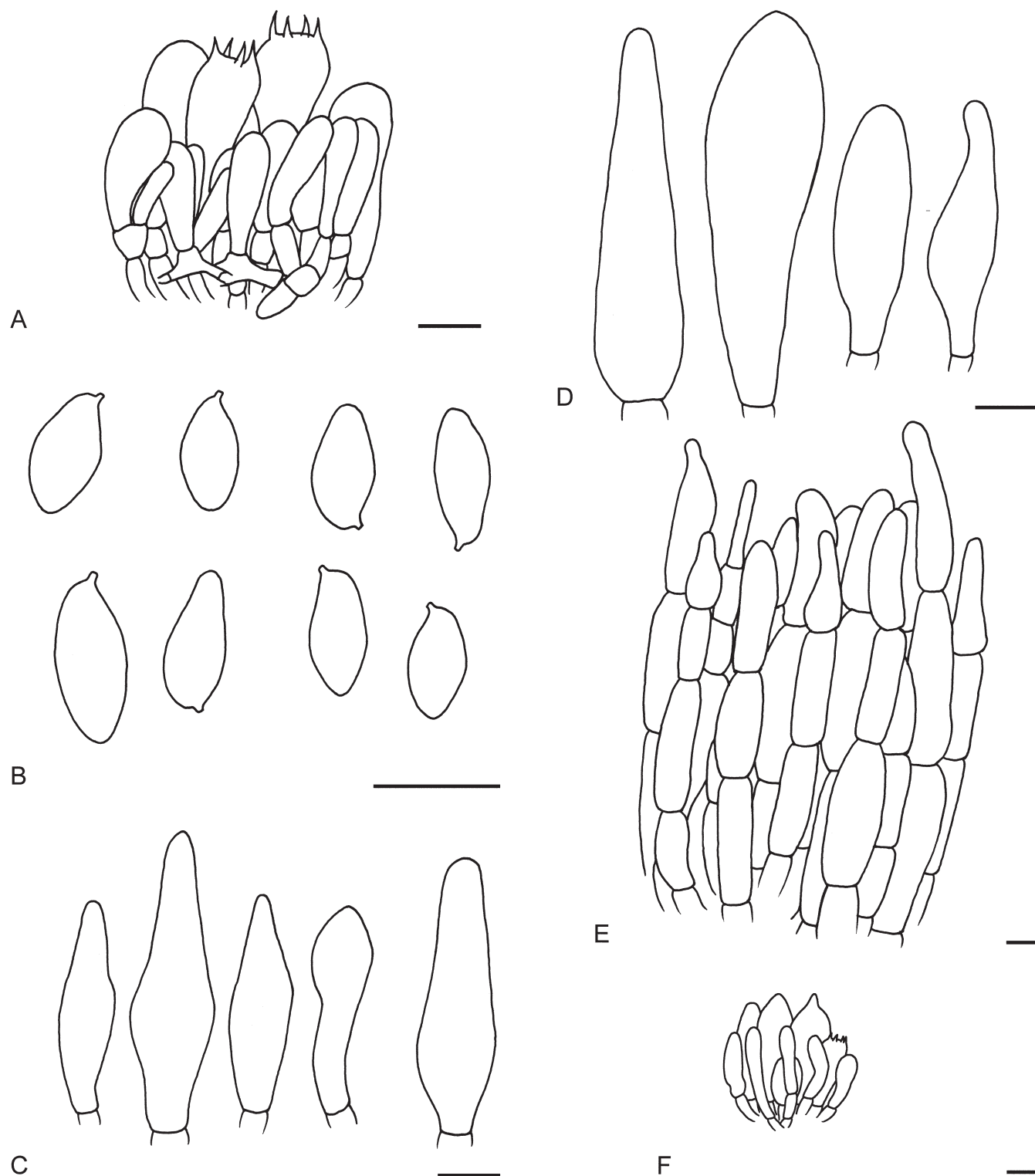
**Typus:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rain Forest National Park, elev. 650 m, 13 Aug. 2020, N.K. Zeng, Zeng4678 (**holotype** FHMU4922).

**Additional materials examined:** **China**, Hainan Province, Yinggeling of Hainan Tropical Rain Forest National Park, elev. 650 m, 30 Jul. 2017, N.K. Zeng, Zeng3190 (FHMU2151); same location, 13 Aug. 2020, N.K. Zeng, Zeng4664, 4672, 4677 (FHMU4940, 4967, 4925).

**Description:** *Basidiomata* small to medium-sized. *Pileus* 3–6.5 cm diam, convex to applanate, margin decurved, usually uplift when old; surface dry, subtomentose, yellowish brown (4B5), brown (5D4) to dark brown (6D6); context 0.2–1.2 cm thick in the centre of the pileus, white (2A1) to yellowish white (2A3), turning bluish when injured. *Hymenophore* poroid, slightly depressed around apex of stipe; pores angular to subround, 0.5–1 mm diam, yellow (3A6), turning bluish when injured; tubes 0.15–0.3 cm in length, yellowish (2A6), turning bluish when injured. *Stipe* 2.7–5.5 × 0.25–1 cm, central, subcylindric; surface dry, densely covered with minute, yellowish brown (5C5) to reddish brown (6D7) squamules; context white (2A1) to yellowish white (2A3), turning bluish when injured; annulus absent; basal mycelium white (2A1). *Odour* indistinct.

*Basidia* 27–34 × 9–11 µm, clavate, thin-walled, 4-spored, colourless in KOH; sterigmata 3–6 µm long. *Basidiospores* [120/6/5] 9–11(–12) × 4–5 µm, Q = (1.8–)2.2–2.8(–3.0), Qm = 2.47 ± 0.21, subfusiform, slightly thick-walled (up to 0.5 µm), yellowish brown in KOH, smooth under both light microscopy and SEM. *Hymenophoral trama* composed of thin- to slightly thick-walled (up to 0.5 µm) hyphae, 5–15 µm wide, colourless in KOH. *Cheilocystidia* 16–53 × 5–14 µm, subfusiform or fusiform, thin-walled, colourless in KOH. *Pileipellis* a trichoderm 200–300 µm thick, composed of hyphae thin- to slightly thick-walled (up to 1 µm), light yellow in KOH, 4–18 µm in width; terminal cell 17–52 × 6–16 µm, clavate, subcylindrical or subfusiform, with obtuse apex. *Pileal trama* made up of hyphae 4–20 µm diam, slightly thick-walled (up to 1 µm), colourless in KOH. *Stipitipellis* a trichoderm-like structure 60–100 µm thick, composed of thin- to slightly thick-walled (up to 1 µm), 4–9 µm wide, light yellow in KOH, emergent hyphae with subfusiform, subcylindrical or clavate terminal cells (11–32 × 5–9 µm). *Stipe trama* composed of cylindrical, light yellow in KOH, slightly thick-walled (up to 1 µm), parallel hyphae 3–19 µm wide. *Clamp connections* absent in all tissues.

**Habitat:** Solitary to scattered on the ground in forests dominated by fagaceous trees.



**Fig. 59.** Microscopic features of *Xerocomus albotomentosus* (holotype FHMU2974). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10 µm. Drawings by H.J. Xie.

*Known distribution:* Southern China (Hainan Province).

*Notes:* In China, *X. fuscatus* was misidentified as *X. microcarpoides*, originally described from Malaysia (Corner 1972), however, *X. microcarpoides* has a very small basidioma and larger basidiospores measuring  $10\text{--}17 \times 4.5\text{--}5.7$  µm (Corner 1972). *Xerocomus fuscatus* is also morphologically similar to *X. illudens*, *X. subtomentosus*, and *X. tenax*. However, *X. illudens* has a pileus

tinged with pinkish, a stipe usually marked by coarse ridges and anastomosing lines, longer basidiospores measuring  $10\text{--}14 \times 4\text{--}5$  µm, hyphae in pileipellis uninflated (up to 10 µm), and it is distributed in North America (Singer 1945c, Smith & Thiers 1971); *X. subtomentosus* has a larger basidioma (pileus up to 15 cm diam), larger basidiospores measuring  $9.8\text{--}14.8 \times 3.9\text{--}6$  µm, and it is distributed in temperate region (Hills 2008); *X. tenax*, originally described from North America, has a larger basidioma (pileus up

to 10 cm diam), a conspicuously reticulate stipe, and hyphae in pileipellis uninflated (up to 10  $\mu\text{m}$ ) (Smith & Thiers 1971, Halling *et al.* 2015). Phylogenetically, *X. fuscatus* is closely related to *X. subparvus* (Fig. 6), however, the latter has a pale yellowish brown to yellow stipe with fine longitudinal striations, narrower basidiospores (9–10.5  $\times$  3.5–4  $\mu\text{m}$ ) with bacillate ornamentation under SEM (Wu *et al.* 2016).

***Xerocomus piceicola*** M. Zang & M.S. Yuan, Acta Bot. Yunnan. 21: 39. 1999.

**Known distribution:** Northwestern (Gansu Province) and southwestern China (Sichuan and Yunnan Provinces) (Zang & Yuan 1999, Wu *et al.* 2016).

**Holotype:** KUN-HKAS30540 (China, Gansu Province).

**Notes:** *Xerocomus piceicola* was originally described from Gansu Province, northwestern China (Zang & Yuan 1999); illustrations

and a full description of the species have been provided by Wu *et al.* (2016).

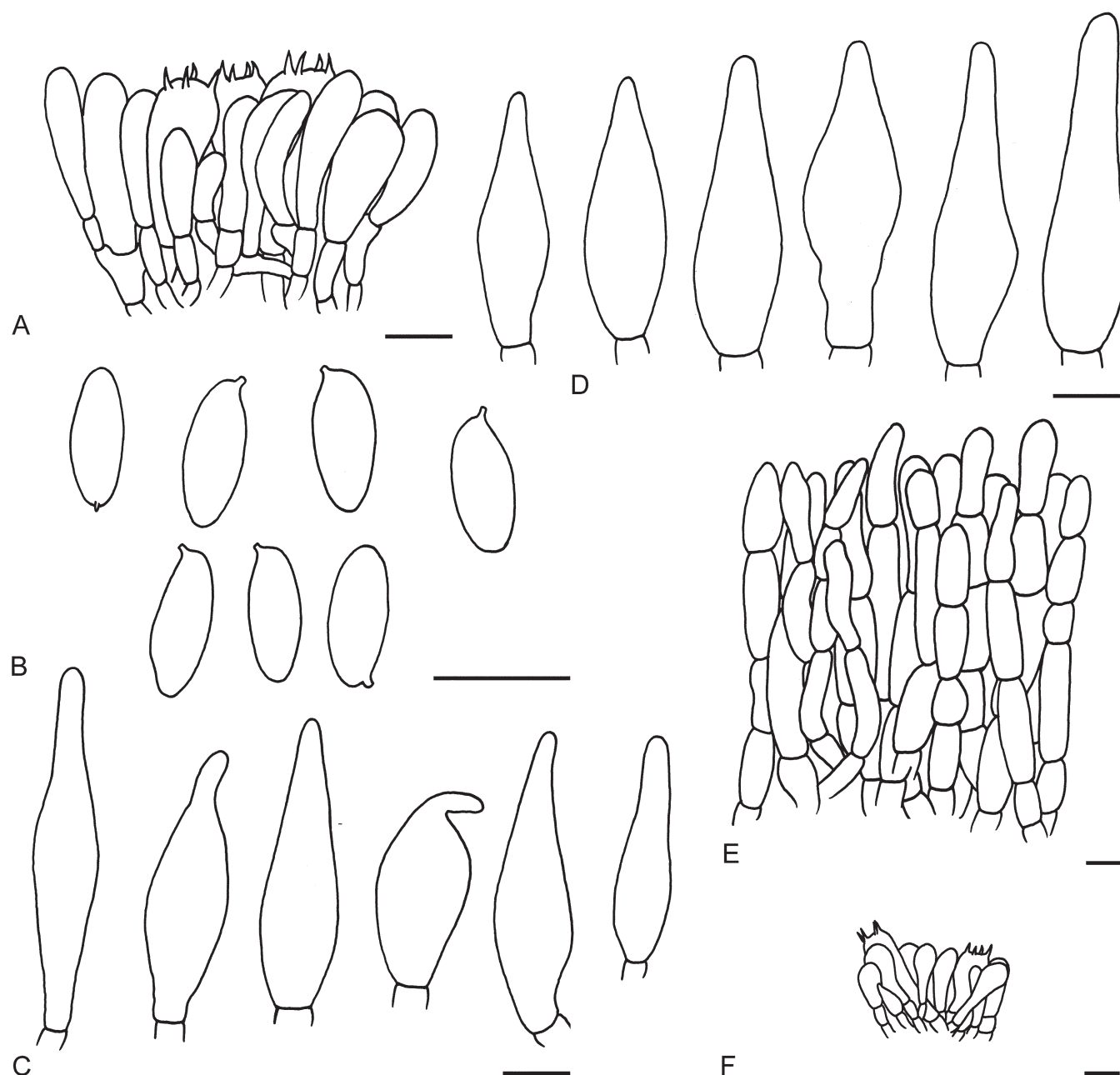
***Xerocomus puniceiporus*** T.H. Li *et al.*, Mycotaxon 121: 24. 2012. MycoBank MB 563347.

**Known distribution:** Southern China (Guangdong Province) (Zhang *et al.* 2012, Wu *et al.* 2016).

**Holotype:** GDGM27443 (China, Guangdong Province).

**Material examined:** **China**, Guangdong Province, Fengkai County, Heishiding Mountain, 2 Jun. 2013, elev. 800 m, K. Zhao, Zhao258 (KUN-HKAS80683).

**Notes:** *Xerocomus puniceiporus* was originally described from Guangdong Province, southern China (Zhang *et al.* 2012); illustrations and a full description of the species have been provided by Zhang *et al.* (2012) and Wu *et al.* (2016).



**Fig. 60.** Microscopic features of *Xerocomus fuscatus* (holotype FHMU4922). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10  $\mu\text{m}$ . Drawings by H.J. Xie.



***Xerocomus rugosellus*** (W.F. Chiu) F.L. Tai, Syll. Fung. Sinicorum: 815. 1979. MycoBank MB 116209. Figs 56H, I, 61.

*Basionym:* *Boletus rugosellus* W.F. Chiu, Mycologia 40: 219. 1948.

*Description:* *Basidiomata* small, medium to large-sized. *Pileus* 3.2–7.3 cm diam, convex to applanate, margin decurved; surface dry, subtomentose, light greyish brown, greyish brown to light yellowish brown; context 0.6–0.7 cm thick in the centre of the pileus, yellowish white to light yellow, turning bluish slowly or indistinctly when injured. *Hymenophore* poroid, slightly decurrent to slightly depressed around apex of stipe; pores subround to round, 0.5–0.8 mm diam, yellow, turning bluish, then reddish brown when injured; tubes 0.5–0.8 mm in length, yellow, turning bluish when injured. *Stipe* 7–7.5 × 0.8–0.9 cm, central, subcylindric; surface dry, light dirty yellow to yellowish white, tinged with dirty pink; context yellowish white, unchanging in colour when injured; annulus absent; basal mycelium white. *Odour* indistinct.

*Basidia* 29–37 × 12–15 µm, clavate, thin-walled, 4-spored, colourless in KOH; sterigmata 2–9 µm long. *Basidiospores* [40/2/2] (11–)12–14.5(–15) × 4–6(–6.5) µm,  $Q = 2.0\text{--}3.1(–3.5)$ ,  $Q_m = 2.51 \pm 0.35$ , subfusiform, slightly thick-walled (up to 0.5 µm), brownish yellow in KOH, smooth in light microscopy, with bacillate surface ornamentation under SEM. *Hymenophoral trama* composed of thin- to slightly thick-walled (up to 0.5 µm) hyphae, 4–14 µm wide, colourless in KOH. *Cheilocystidia* 36–77 × 9–20 µm, subfusiform or fusiform, thin-walled, colourless in KOH. *Pleurocystidia* 65–90 × 10–17 µm, subfusiform or fusiform, thin-walled, colourless in KOH. *Pileipellis* a trichoderm 240–300 µm thick, composed of hyphae thin- to slightly thick-walled (up to 0.5 µm), colourless in KOH, 7–17 µm in width; terminal cell 28–63 × 9–17 µm, clavate, subcylindrical or subfusiform, with obtuse apex. *Pileal trama* made up of hyphae 5–16 µm diam, slightly thick-walled (up to 0.5 µm), colourless in KOH. *Stipitipellis* a trichoderm-like structure 60–80 µm thick, composed of thin- to slightly thick-walled (up to 0.8 µm), 4–14 µm wide, colourless to light yellow in KOH, emergent hyphae with subfusiform, subcylindrical or clavate terminal cells (12–39 × 7–11 µm). *Stipe trama* composed of cylindrical, colourless to light yellow in KOH, slightly thick-walled (up to 0.9 µm), parallel hyphae 4–18 µm wide. *Clamp connections* absent in all tissues.

*Habitat:* Scattered on the ground in mixed forests dominated by fagaceous trees (*Quercus* spp.) and *Pinus yunnanensis*.

*Known distribution:* Southwestern China (Yunnan Province).

*Holotype:* HMAS03872 (China, Yunnan Province).

*Materials examined:* **China**, Yunnan Province, Jianchuan County, Shibaoshan Scenic Spot, elev. 2 504 m, 12 Sep. 2019, H.Y. Huang, Huang490 (FHMU6029); same location, elev. 2 528 m, 14 Sep. 2019, H.Y. Huang, Huang529 (FHMU6011).

*Notes:* *Xerocomus rugosellus* was described from Yunnan Province, southwestern China (Chiu 1948). It was placed in the genus *Boletus* firstly (Chiu 1948), then transferred to *Xerocomus* (Tai 1979). The amended descriptions of the species were provided by Wu *et al.* (2016) and us. The species is characterised by a small, medium to large-sized basidioma, a yellow hymenophore, and larger basidiospores measuring 12–14.5 × 4–6 µm, with bacillate ornamentation under SEM. We also noted that the young pileal surface was described as “rugose” (Wu *et al.* 2016) whereas this was not observed in our new collections.

***Xerocomus subparvus*** Xue T. Zhu & Zhu L. Yang, Fungal Diversity 81: 181. 2016. MycoBank MB 818504. Figs 57A–C, 62.

*Description:* *Basidiomata* small to medium-sized. *Pileus* 3.2–6 cm diam, convex to applanate, margin decurved, sometimes uplift; surface dry, subtomentose, yellowish brown, brown to reddish brown; context 0.6–1 cm thick in the centre of the pileus, white, turning bluish when injured. *Hymenophore* poroid, slightly decurrent around apex of stipe; pores angular, about 0.5 mm diam, yellow, turning blue distinctly when injured; tubes 0.3–0.7 cm in length, light yellow, turning bluish when injured. *Stipe* 2.8 × 0.5 cm, central, subcylindric; surface dry, yellowish brown to reddish brown; context white, turning bluish when injured; annulus absent; basal mycelium white. *Odour* indistinct.

*Basidia* 20–28 × 7–10 µm, clavate, thin-walled, 4-spored, colourless in KOH; sterigmata 3–6 µm long. *Basidiospores* [60/3/3] 9–12(–14) × 4–5 µm,  $Q = (1.8\text{--})2.0\text{--}2.8(–2.8)$ ,  $Q_m = 2.37 \pm 0.22$ , subfusiform, slightly thick-walled (up to 0.5 µm), yellowish brown in KOH, smooth under light microscopy, with bacillate ornamentation under SEM. *Hymenophoral trama* composed of thin- to slightly thick-walled (up to 0.5 µm) hyphae, 4–13 µm wide, colourless in KOH. *Cheilocystidia* 18–46 × 6–17 µm, subfusiform or fusiform, thin-walled, colourless to light yellow in KOH. *Pleurocystidia* 18–62 × 10–19 µm, subfusiform or fusiform, thin-walled, colourless to light yellow in KOH. *Pileipellis* a trichoderm 100–160 µm thick, composed of hyphae thin- to slightly thick-walled (up to 1 µm), colourless to light yellow in KOH, 6–16 µm in width; terminal cell 23–105 × 11–21 µm, clavate, subcylindrical or subfusiform, with obtuse apex. *Pileal trama* made up of hyphae 4–20 µm diam, slightly thick-walled (up to 0.8 µm), colourless in KOH. *Stipitipellis* a trichoderm-like structure 60–100 µm thick, composed of thin- to slightly thick-walled (up to 1 µm), 3–10 µm wide, light yellow in KOH, emergent hyphae with subfusiform, subcylindrical or clavate terminal cells (17–30 × 3–10 µm). *Stipe trama* composed of cylindrical, light yellow in KOH, slightly thick-walled (up to 1 µm), parallel hyphae 3–17 µm wide. *Clamp connections* absent in all tissues.

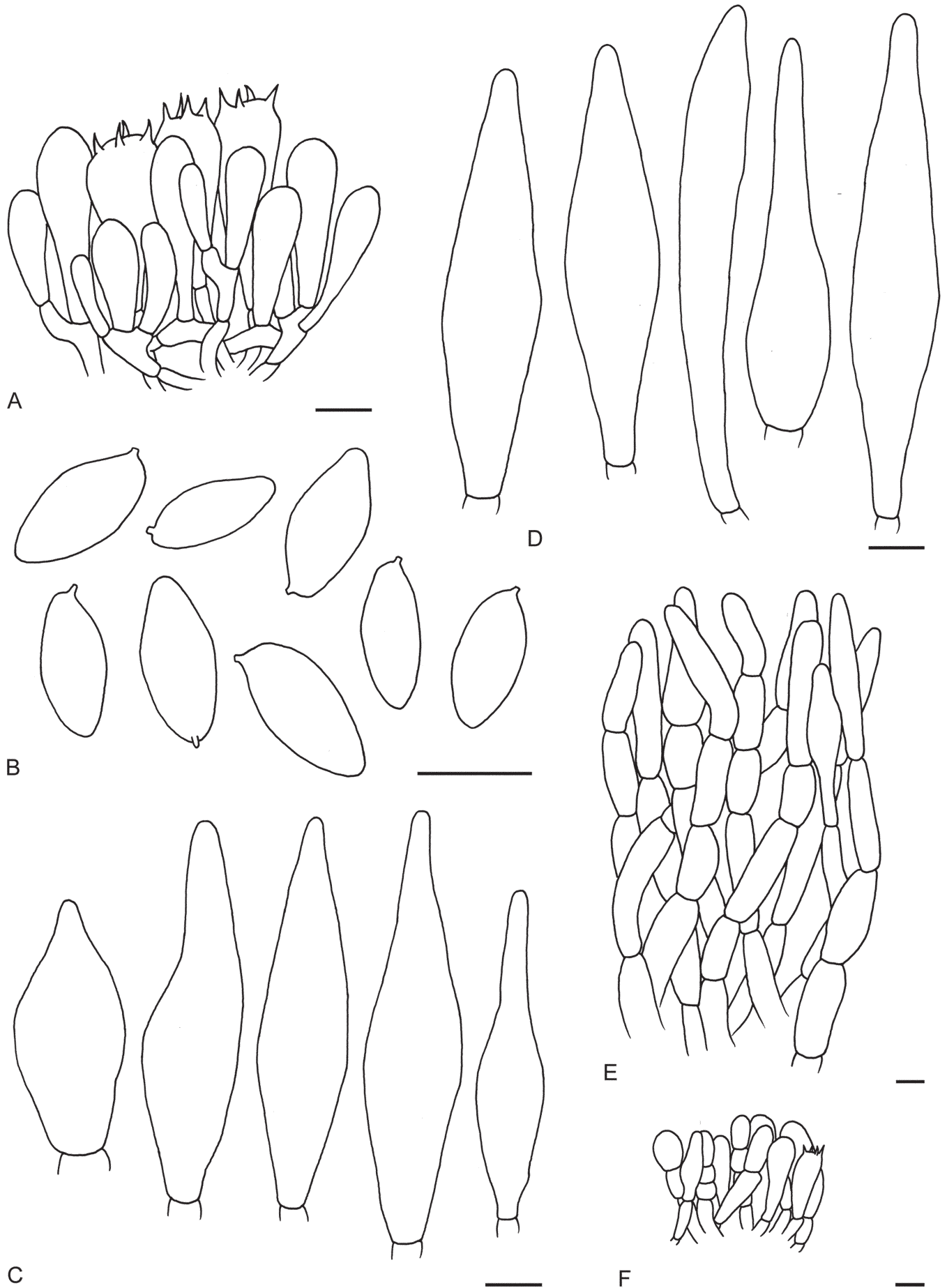
*Habitat:* Scattered on the ground in forests dominated by fagaceous trees.

*Known distribution:* Central (Hunan Province), southeastern (Fujian Province), eastern (Zhejiang Province), and southern China (Hainan Province) (Wu *et al.* 2016).

*Holotype:* KUN-HKAS50295 (China, Yunnan Province).

*Materials examined:* **China**, Hainan Province, Yinggeling, Hainan Tropical Rain Forest National Park, elev. 850 m, 3 Aug. 2015, N.K. Zeng, Zeng2510 (FHMU1630); same location, elev. 560 m, 25 Apr. 2019, N.K. Zeng, Zeng4049 (FHMU3344); Fujian Province, Tianbaoyan National Nature Reserve, elev. 350 m, 17 Aug. 2017, N.K. Zeng, Zeng3280 (FHMU2241); Hunan Province, Zhangjiajie National Nature Reserve, 12 Aug. 2020, Z.H. Chen, IMG4569 (FHMU6121); Zhejiang Province, Zhoushan City, elev. 35 m, Y. Li, Li3109, 3166 (FHMU6901, 6904).

*Notes:* *Xerocomus subparvus* was originally described from Yunnan Province, southwestern China (Wu *et al.* 2016). Besides Yunnan, Fujian, and Guangdong Provinces of China (Wu *et al.* 2016), it was also reported from tropical China (Hainan Province) and Vietnam (Pham & Morozova 2020, Zeng & Jiang 2020). In the present study, it was found to distributed in Hunan and Zhejiang Provinces of China. The species is characterised by a small to medium-sized basidioma, a yellow hymenophore, a yellow brown



**Fig. 61.** Microscopic features of *Xerocomus rugosellus* (FHMU6029). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stipitipellis. Scale bars = 10  $\mu$ m. Drawings by H.J. Xie.

to reddish brown stipe, a context turning bluish when injured, and smaller basidiospores measuring  $9\text{--}12 \times 4\text{--}5 \mu\text{m}$ , with bacillate ornamentation under SEM.

***Xerocomus velutinus*** Xue T. Zhu & Zhu L. Yang, Fungal Diversity 81: 182. 2016. MycoBank MB 818505.

*Known distribution:* Southwestern China (Yunnan Province) (Wu et al. 2016).

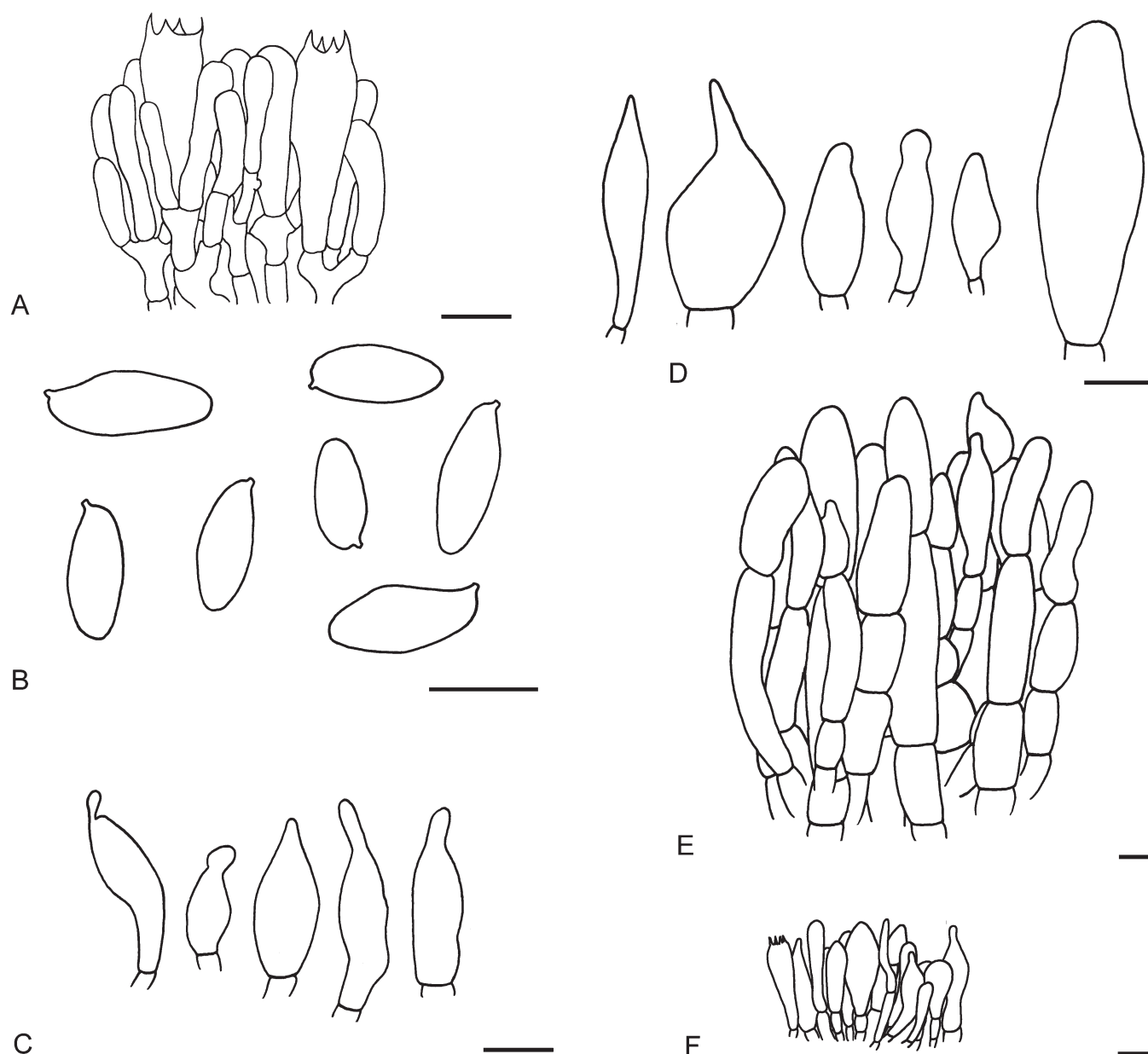
*Holotype:* KUN-HKAS68135 (China, Yunnan Province).

*Notes:* *Xerocomus velutinus* was originally described from Yunnan Province, southwestern China (Wu et al. 2016). Illustrations and a full description of the species have been provided by Wu et al. (2016).

***Xerocomus yunnanensis*** (W.F. Chiu) F.L. Tai, Syll. Fung. Sinicorum: 816. 1979. MycoBank MB 116207. Figs 57D–F, 63. *Basionym:* *Boletus yunnanensis* W.F. Chiu, Mycologia 40: 217. 1948.

*Description:* *Basidiomata* very small-sized. *Pileus* 1.5–2 cm diam, convex to applanate, margin decurved; surface dry, tomentose, yellowish brown to reddish brown; context about 0.2 cm thick in the centre of the pileus, white, unchanging in colour when injured. *Hymenophore* poroid, slightly decurrent around apex of stipe; pores subround to round, 0.3–0.5 mm diam, yellow, turning bluish when injured; tubes 0.2–0.4 cm in length, yellow, turning bluish when injured. *Stipe* 3.5–4 × 0.4–0.6 cm, central, subcylindric; surface dry, yellowish white to yellow; context light yellow, unchanging in colour when injured; annulus absent; basal mycelium white. *Odour* indistinct.

*Basidia*  $27\text{--}35 \times 11\text{--}13 \mu\text{m}$ , clavate, thin-walled, 4-spored, colourless in KOH; sterigmata 2–5  $\mu\text{m}$  long. *Basidiospores*  $[40/2/2]$   $9\text{--}12 \times 4\text{--}5(-5.5) \mu\text{m}$ ,  $Q = 2.0\text{--}2.8(-2.9)$ ,  $Q_m = 2.33 \pm 0.20$ , subfusiform, slightly thick-walled (up to  $0.5 \mu\text{m}$ ), yellowish brown in KOH, smooth under light microscopy, with bacillate surface ornamentation under SEM. *Hymenophoral* trama composed of thin- to slightly thick-walled (up to  $0.5 \mu\text{m}$ ) hyphae, 4–15  $\mu\text{m}$  wide, colourless in KOH. *Cheilocystidia*  $22\text{--}65 \times 7\text{--}18 \mu\text{m}$ , subfusiform or fusiform, thin-walled, colourless in KOH. *Pleurocystidia*  $32\text{--}62 \times$



**Fig. 62.** Microscopic features of *Xerocomus subparvus* (FHMU2241). **A.** Basidia. **B.** Basidiospores. **C.** Cheilocystidia. **D.** Pleurocystidia. **E.** Pileipellis. **F.** Stiptipellis. Scale bars = 10  $\mu\text{m}$ . Drawings by H.J. Xie.



10–19 µm, subfusiform or fusiform, thin-walled, colourless in KOH. *Pileipellis* a trichoderm 120–230 µm thick, composed of hyphae thin- to slightly thick-walled (up to 1 µm), yellow to brownish yellow in KOH, 4–12 µm in width; terminal cell 12–31 × 4–12 µm, clavate, subcylindrical or subfusiform, with obtuse apex. *Pileal trama* made up of hyphae 3–16 µm diam, slightly thick-walled (up to 0.8 µm), colourless in KOH. *Stipitipellis* a trichoderm-like structure 80–100 µm thick, composed of thin- to slightly thick-walled (up to 1 µm), 3–9 µm wide, light yellow in KOH, emergent hyphae with subfusiform, subcylindrical or clavate terminal cells (12–24 × 4–9 µm). *Stipe trama* composed of cylindrical, light yellow in KOH, slightly thick-walled (up to 1 µm), parallel hyphae 3–15 µm wide. *Clamp connections* absent in all tissues.

*Habitat*: Solitary on the ground in forests dominated by fagaceous trees.

*Known distribution*: Southwestern China (Yunnan Province).

*Holotype*: HMAS03900 (China, Yunnan Province).

*Materials examined*: **China**, Yunnan Province, Jinping County, Fenshuiling National Nature Reserve, 12 Jul. 2018, N.K. Zeng, Zeng3559 (FHMU3071); same location, 12 Jul. 2018, N.K. Zeng, Zeng3561 (FHMU3059).

*Notes*: *Xerocomus yunnanensis* was described from Yunnan Province, southwestern China (Chiu 1948). It was placed in the genus *Boletus* firstly (Chiu 1948), then transferred to *Xerocomus* (Tai 1979). The amended descriptions of the species were provided by Wu *et al.* (2016) and us. The species is characterised by a small basidioma, a yellow hymenophore, a yellow white to yellow stipe, and smaller basidiospores measuring 9–12 × 4–5 µm, with bacillate ornamentation under SEM.

## Key to accepted species of *Xerocomus* in China

- 1a. Hymenophoral surface vivid red, red to dark red, brownish red; tubes yellow ..... *X. puniceiporus*
- 1b. Both hymenophoral surface and tubes yellow ..... 2
- 2a. Basidiospores smooth under both light microscopy and SEM ..... 3
- 2b. Basidiospores smooth under light microscopy, with bacillate ornamentation under SEM ..... 4
- 3a. Basidiospores comparatively small measuring 9–11 × 4–5 µm, distribution in subtropical or tropical forests dominated by fagaceous trees ..... *X. fuscatulus*
- 3b. Basidiospores comparatively large measuring 13.5–14.5 × 5–5.5 µm, distribution in subalpine forests dominated by *Abies* and/or *Picea* ..... *X. piceicola*
- 4a. Basidiospores comparatively large (up to 14.5 µm in length) ..... 5
- 4b. Basidiospores comparatively small (up to 12 µm in length) ..... 6
- 5a. Basidioma comparatively large (pileus > 5 cm diam) ..... *X. rugosellus*
- 5b. Basidioma comparatively small (pileus ≤ 5 cm diam) ..... *X. velutinus*
- 6a. Stipe surface yellowish white to yellow ..... *X. yunnanensis*
- 6b. Stipe surface yellowish brown, brown or reddish brown ..... 7
- 7a. Basidioma comparatively small (pileus ≤ 6 cm diam) ..... 8
- 7b. Basidioma comparatively small (pileus > 6 cm diam) ..... 9
- 8a. Context unchanging in colour when injured ..... *X. albotomentosus*
- 8b. Context turning bluish when injured ..... *X. subparvus*
- 9a. Stipe surface pale yellowish brown to pale brown, and an absence of reddish ..... *X. fraternus*
- 9b. Stipe surface reddish brown ..... *X. fulvipes*

## DISCUSSION

High species diversity of the subfamily *Xerocomoideae* in China was revealed in this study, and 103 species-level lineages (37 of *Aureoboletus*, 15 of *Boletellus*, seven of *Hemileccinum*, 31 of *Phylloporus*, one of *Pulchroboletus*, and 12 of *Xerocomus*) of the subfamily were identified (Figs 1–6). Based on morphological studies of new collections and re-examinations holotypes of some species, combined with previous studies, 13 new species (three of *Aureoboletus*, five of *Boletellus*, one of *Hemileccinum*, one of *Phylloporus*, one of *Pulchroboletus*, and two of *Xerocomus*) of *Xerocomoideae* were described, and 84 previous species (26 of *Aureoboletus*, 12 of *Boletellus*, four of *Heimioporus*, six of

*Hemileccinum*, four of *Hourangia*, 24 of *Phylloporus*, and eight of *Xerocomus*) were confirmed to be distributed in China (Table 2). Among the 97 accepted species of *Xerocomoideae*, only two species, viz. *A. quercus-spinosae* and *X. piceicola* grow in temperate areas (Wu *et al.* 2016, Zhang *et al.* 2017), one species, viz. *A. zangii* occurs in temperate and subtropical regions (Shi & Liu 2013, Wu *et al.* 2016); the other 94 species are distributed in tropical and subtropical regions. The geographical distribution pattern indicated that the subtropical-tropical region of China is the current species diversity centre of *Xerocomoideae*.

*Aureoboletus mirabilis*, originally described from North America (Murrill 1912), was also reported to be distributed in China (Wu *et al.* 2016). However, our molecular data indicated that one Chinese collection identified as *A. mirabilis* is genetically distinct from North

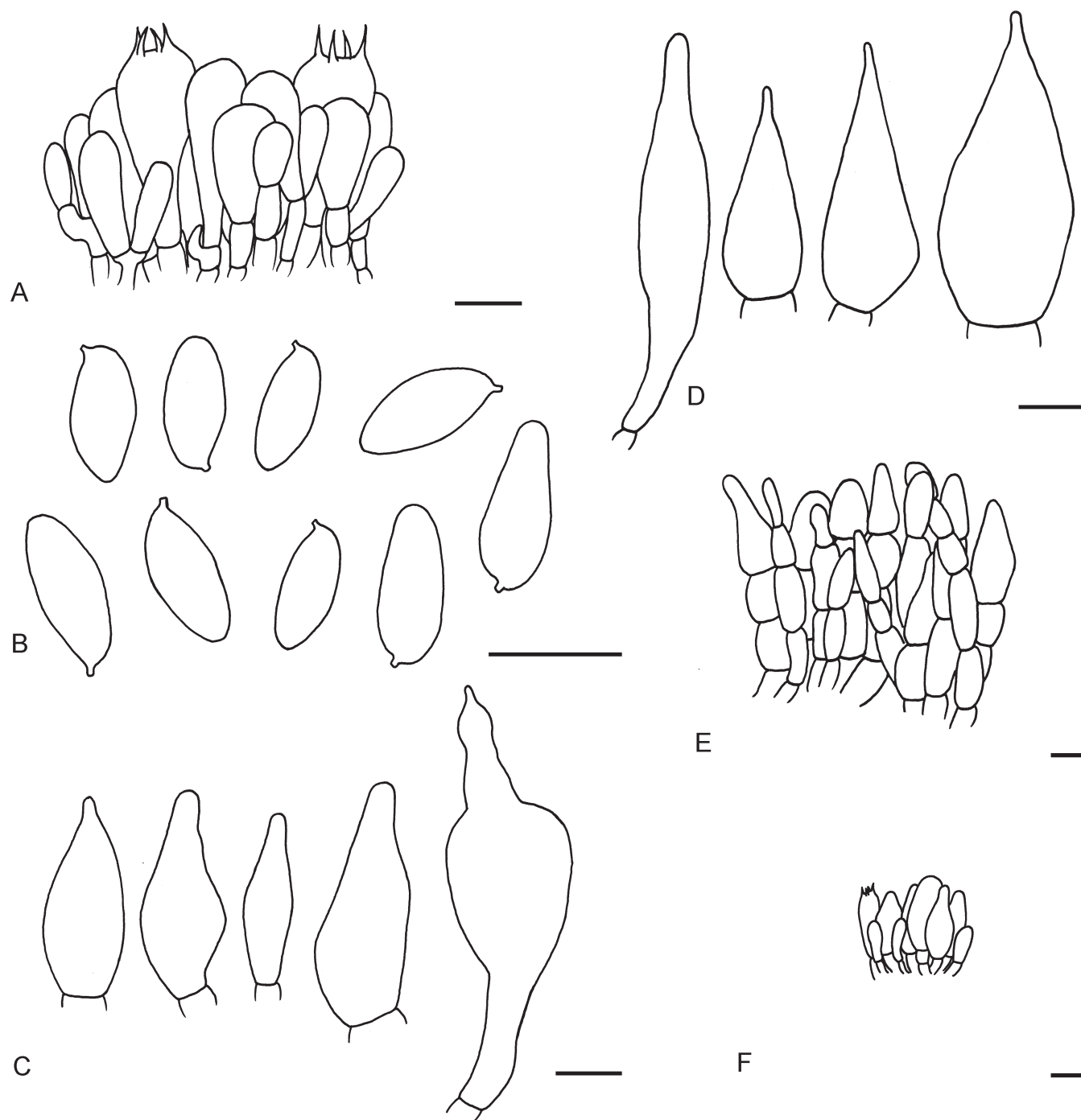


Fig. 63. Microscopic features of *Xerocomus yunnanensis* (FHMU3059). A. Basidia. B. Basidiospores. C. Cheilocystidia. D. Pleurocystidia. E. Pileipellis. F. Stipitipellis. Scale bars = 10  $\mu$ m. Drawings by H.J. Xie.

American *A. mirabilis* (Fig. 1). The occurrence of *A. mirabilis* in China should be further defined in the future.

Our molecular data indicated that the collections named "*Bol. emodensis*" were present in four parts of the tree (Fig. 2). According to our careful examinations, lineage 1 including collections from northeastern India, China, and Japan corresponds to true *Bol. emodensis*, and that *Bol. aurocontextus* is probably a synonym of *Bol. emodensis*. Other collections identified as "*Bol. emodensis*" from Australia, Thailand, and Japan, respectively (Fig. 2), should be further studied. Besides several species of *Boletellus* defined based on morphological and molecular phylogenetic evidence (see above), there are many other species originally described from China, viz. *Bol. fanjingensis*, *Bol. fujianensis*, *Bol. radiates*,

*Bol. serpentipileus*, *Bol. taiwanensis*, *Bol. violaceus*, and *Bol. yunnanensis* (Table 2), which have no molecular data from the type specimens. To re-evaluate these taxa, more collections from a wide area (including the type locality), and more DNA sequence data should be obtained before elucidating their true taxonomic relationship to other *Boletellus* species. *Boletellus elatus*, a species reported to be distributed in China (Li & Song 2003), still needs further information to assess the phylogenetic position for the species may probably represent a new genus according to one previous molecular phylogenetic analysis (Halling *et al.* 2015).

Besides several species of *Xerocomus* defined based on morphological and molecular phylogenetic evidence (see above), there are several other species originally described from China, viz.

**Table 2.** List of described, reported and controversial *Xerocomoideae* species in China.

Species	Type locality	Treatment	References
<i>Aureoboletus albipes</i>	Fujian, SE China	Accepted	This study
<i>A. betula</i>	North America	Confirmed as absent from China	Schweinitz (1822), Li & Song (2003)
<i>A. catenarius</i>	Yunnan, SW China	Accepted	Wu <i>et al.</i> (2016)
<i>A. clavatus</i>	Hainan, southern China	Accepted	Zeng <i>et al.</i> (2015)
<i>A. conicus</i>	Hainan, southern China	Accepted	This study
<i>A. duplicatoporus</i>	Yunnan, SW China	Accepted	Zang (1992)
<i>A. erythraeus</i>	Hainan, southern China	Accepted	Wang <i>et al.</i> (2020)
<i>A. formosus</i>	Hunan, central China	Accepted	Zhang <i>et al.</i> (2015a)
<i>A. glutinosus</i>	Hunan, central China	Accepted	Zhang <i>et al.</i> (2019a)
<i>A. griseorufescens</i>	Guangdong, southern China	Accepted	Zhang <i>et al.</i> (2019a)
<i>A. guangdongensis</i>	Guangdong, southern China	Accepted	Zhang <i>et al.</i> (2022)
<i>A. longicollis</i>	Malaysia	Accepted	Cesati (1879), Zhang <i>et al.</i> (2019a)
<i>A. marroninus</i>	Guangdong, southern China	A synonym of <i>A. tenuis</i>	Zhang <i>et al.</i> (2015)
<i>A. microcarpus</i>	Hainan, southern China	Accepted	Zhang <i>et al.</i> (2022)
<i>A. miniatoaurantiacus</i>	Guangdong, southern China	Accepted	Bi <i>et al.</i> (1982)
<i>A. mirabilis</i>	North America	Confirmed as absent from China	Murrill (1912), Wu <i>et al.</i> (2014)
<i>A. nephrosporus</i>	Yunnan, SW China	Accepted	Wu <i>et al.</i> (2016)
<i>A. ornaticipes</i>	Hainan, southern China	Accepted	This study
<i>A. quercus-spinosae</i>	Tibet, SW China	Accepted	Zhang <i>et al.</i> (2017)
<i>A. raphanaceus</i>	Jiangxi, eastern China	Accepted	Zhang <i>et al.</i> (2019a)
<i>A. reticuloceps</i>	Sichuan, SW China	Transferred to <i>Boletus</i>	Zang <i>et al.</i> (1993), Wang <i>et al.</i> (2005)
<i>A. rubellus</i>	Jiangxi, eastern China	Accepted	Fang <i>et al.</i> (2019)
<i>A. rugosus</i>	Yunnan, SW China	Accepted	Zhang <i>et al.</i> (2022)
<i>A. russellii</i>	North America	Confirmed as absent from China	Frost (1874), Li & Song (2003)
<i>A. shichianus</i>	Zhejiang, eastern China	Accepted	Teng (1932), Wu <i>et al.</i> (2016)
<i>A. sinobadius</i>	Guangdong, southern China	Accepted	Zhang <i>et al.</i> (2019a)
<i>A. solus</i>	Guangdong, southern China	Accepted	Zhang <i>et al.</i> (2019a)
<i>A. tenuis</i>	Guangxi, southern China	Accepted	Zhang <i>et al.</i> (2014)
<i>A. thibetanus</i>	Sichuan, SW China	Accepted	Patouillard (1895), Yang <i>et al.</i> (2003)
<i>A. tomentosus</i>	Guangdong, southern China	A synonym of <i>A. miniatoaurantiacus</i>	Wu <i>et al.</i> (2016)
<i>A. velutipes</i>	Guangdong, southern China	Accepted	Zhang <i>et al.</i> (2019a)
<i>A. venustus</i>	Guangdong, southern China	Accepted	Li <i>et al.</i> (2016)
<i>A. viscidipes</i>	Japan	Accepted	Hongo (1974), Wu <i>et al.</i> (2016)
<i>A. viscosus</i>	Guangdong, southern China	Probably a synonym of <i>A. longicollis</i>	Bi <i>et al.</i> (1982)
<i>A. yunnanensis</i>	Yunnan, SW China	Accepted	Wu <i>et al.</i> (2016)
<i>A. zangii</i>	Shaanxi, NW China	Accepted	Shi & Liu (2013)
<i>Boletellus</i> aff. <i>putuoensis</i>	Hainan, southern China	Accepted	This study
<i>Bol. ananas</i>	North America	Confirmed as absent from China	Curtis (1848), Li & Song (2003)
<i>Bol. ananiceps</i>	Australia	Confirmed as absent from China	Berkeley (1873), Li & Song (2003)
<i>Bol. areolatus</i>	Japan	Accepted	Sato & Hattori (2015)
<i>Bol. aurocontextus</i>	Japan	Probably a synonym of <i>Bol. emodensis</i>	Sato & Hattori (2015)
<i>Bol. badiovinosus</i>	Papua New Guinea	Confirmed as absent from China	Horak (1977), Wen (1985)
<i>Bol. brunoflavus</i>	Guangdong, southern China	Accepted	Lin <i>et al.</i> (2022)
<i>Bol. betula</i>	North America	Transferred to <i>Aureoboletus</i>	Schweinitz (1822), Li & Song (2003), Kuo <i>et al.</i> (2020)
<i>Bol. chrysenteroides</i>	North America	Confirmed as absent from China	Snell (1936), Li & Song (2003)



Table 2. (Continued).

Species	Type locality	Treatment	References
<i>Bol. elatus</i>	Japan	Accepted, but the phylogenetic position should be re-evaluated	Nagasawa (1984), Li & Song (2003)
<i>Bol. emodensis</i>	India	Accepted	Berkeley (1851), Li & Song (2003)
<i>Bol. erythrolepis</i>	Hainan, southern China	Accepted	This study
<i>Bol. fanjingensis</i>	Guizhou, SW China	Accepted	Wen (1985)
<i>Bol. floriformis</i>	Japan	Confirmed as absent from China	Imazeki (1952), Li & Song (2003)
<i>Bol. fujianensis</i>	Fujian, SE China	Accepted	Wen (1985)
<i>Bol. indistinctus</i>	Guangdong, southern China	Accepted	Wu <i>et al.</i> (2016)
<i>Bol. jalapensis</i>	Mexico	Confirmed as absent from China	Murrill (1910), Li & Song (2003)
<i>Bol. lignicola</i>	Taiwan, eastern China	Re-evaluated	Yeh & Chen (1985)
<i>Bol. longicollis</i>	Malaysia	Transferred to <i>Aureoboletus</i>	Cesati (1879), Li & Song (2003), Zeng <i>et al.</i> (2015)
<i>Bol. mirabilis</i>	North America	Transferred to <i>Aureoboletus</i>	Murrill (1912), Wu <i>et al.</i> (2014), Halling <i>et al.</i> (2015)
<i>Bol. obscurecoccineus</i>	Indonesia	Confirmed as absent from China	Höhnelt (1914), Li & Song (2003)
<i>Bol. obscurecoccineus</i> var. <i>cyanescens</i>	Australia	Confirmed as absent from China	Watling & Li (1999), Li & Song (2003)
<i>Bol. puniceus</i>	Yunnan, SW China	Accepted	Chiu (1948), Wang & Liu (2002)
<i>Bol. putuoensis</i>	Zhejiang, eastern China	Accepted	Xu <i>et al.</i> (2022)
<i>Bol. radiatus</i>	Guangdong, southern China	Re-evaluated	Bi <i>et al.</i> (1984)
<i>Bol. rubidus</i>	Yunnan, SW China	Accepted	This study
<i>Bol. russellii</i>	North America	Transferred to <i>Aureoboletus</i>	Frost (1874), Li & Song (2003), Wu <i>et al.</i> (2016)
<i>Bol. serpentipileus</i>	Sichuan, SW China	Re-evaluated	Zang & Yuan (1999)
<i>Bol. shichianus</i>	Zhejiang, eastern China	Transferred to <i>Aureoboletus</i>	Teng (1932), Wu <i>et al.</i> (2016)
<i>Bol. sinochrysenoides</i>	Jiangxi, eastern China	Accepted	This study
<i>Bol. squamosus</i>	Yunnan, SW China	Accepted	Zang (1985)
<i>Bol. subglobosus</i>	Hainan, southern China	Accepted	This study
<i>Bol. taiwanensis</i>	Taiwan, eastern China	Re-evaluated	Zang <i>et al.</i> (1999)
<i>Bol. violaceus</i>	Fujian, SE China	Accepted	Zang (1985)
<i>Bol. viscosus</i>	Guangdong, southern China	Transferred to <i>Aureoboletus</i>	Bi <i>et al.</i> (1982), Wu <i>et al.</i> (2016)
<i>Bol. vulgaris</i>	Guangdong, southern China	Re-evaluated	Bi <i>et al.</i> (1982)
<i>Bol. wenshanensis</i>	Yunnan, SW China	Accepted	Zhang & Wu (2022)
<i>Bol. xerampelinus</i>	Yunnan, SW China	A synonym of <i>Hei. japonicus</i>	Zang (1985), Zeng <i>et al.</i> (2018)
<i>Bol. yunnanensis</i>	Yunnan, SW China	Accepted	Zang (1985)
<i>Bol. zenghuoxingii</i>	Hainan, southern China	Accepted	This study
<i>Hei. betula</i>	North America	Transferred to <i>Aureoboletus</i>	Schweinitz (1822), Li & Song (2003), Kuo <i>et al.</i> (2020)
<i>Heimioporus conicus</i>	Hainan, southern China	Accepted	Zeng <i>et al.</i> (2018)
<i>Hei. gaojiaocong</i>	Yunnan, SW China	Accepted	Zeng <i>et al.</i> (2018)
<i>Hei. japonicus</i>	Japan	Accepted	Hongo (1969), Zeng <i>et al.</i> (2018)
<i>Hei. nigricans</i>	Yunnan, SW China	A synonym of <i>Strobilomyces zangii</i>	Zang (1985), Gelardi <i>et al.</i> (2013)
<i>Hei. retisporus</i>	Singapore	Confirmed as absent from China	Patouillard (1918), Horak (2011)
<i>Hei. sinensis</i>	Guangdong, southern China	Accepted	Chen <i>et al.</i> (2019)
<i>Hei. subretisporus</i>	Malaysia	Confirmed as absent from China	Corner (1972), Wu <i>et al.</i> (2016)
<i>Hei. xerampelinus</i>	Yunnan, SW China	A synonym of <i>Hei. japonicus</i>	Zang (1985)
<i>Hemileccinum albidum</i>	Yunnan, SW China	Accepted	Li <i>et al.</i> (2021)
<i>H. brevisporum</i>	Yunnan, SW China	Accepted	Li <i>et al.</i> (2021)
<i>H. ferrugineipes</i>	Yunnan, SW China	Accepted	Li <i>et al.</i> (2021)
<i>H. indecorum</i>	Singapore	Accepted	Massee (1914), Zeng <i>et al.</i> (2012)

Table 2. (Continued).

Species	Type locality	Treatment	References
<i>H. parvum</i>	Yunnan, SW China	Accepted	Li <i>et al.</i> (2021)
<i>H. rugosum</i>	Yunnan, SW China	Accepted	Wu <i>et al.</i> (2016)
<i>H. squamipes</i>	Hainan, southern China	Accepted	This study
<i>Hourangia cheoi</i>	Yunnan, SW China	Accepted	Chiu (1948)
<i>Hou. densisquamata</i>	Fujian, SE China	Accepted	Wang <i>et al.</i> (2020)
<i>Hou. dilatata</i>	Hainan, southern China	Accepted	Wang <i>et al.</i> (2020)
<i>Hou. microcarpa</i>	Malaysia	Confirmed as absent from China	Corner (1972), Wu <i>et al.</i> (2016)
<i>Hou. nigropunctata</i>	Yunnan, SW China	Accepted	Chiu (1948)
<i>Phylloporus alboinfuscatus</i>	Hunan, central China	Accepted	Wu <i>et al.</i> (2021)
<i>P. ater</i>	Congo	Confirmed as absent from China	Beeli <i>et al.</i> (1927), Li & Song (2003)
<i>P. bellus</i>	Singapore	Accepted	Massee (1914), Wu <i>et al.</i> (2016)
<i>P. bogoriensis</i>	SE Asia	Accepted	Höhnel (1914), Wu <i>et al.</i> (2021)
<i>P. brunneiceps</i>	Yunnan, SW China	Accepted	Zeng <i>et al.</i> (2013)
<i>P. castanopsidis</i>	Thailand	Accepted	Neves <i>et al.</i> (2012), Zeng & Jiang (2020)
<i>P. depressus</i>	Congo	Confirmed as absent from China	Heinemann (1953), Li & Song (2003)
<i>P. foliiporus</i>	North America	Confirmed as absent from China	Murrill (1943), Li & Song (2003)
<i>P. grossus</i>	Hunan, central China	Accepted	Wu <i>et al.</i> (2021)
<i>P. hainanensis</i>	Hainan, southern China	Accepted	This study
<i>P. imbricatus</i>	Yunnan, SW China	Accepted	Zeng <i>et al.</i> (2013)
<i>P. incarnatus</i>	Singapore	Confirmed as absent from China	Corner (1970), Li & Song (2003)
<i>P. luxiensis</i>	Yunnan, SW China	Accepted	Zang & Zeng (1978)
<i>P. maculatus</i>	Yunnan, SW China	Accepted	Zeng <i>et al.</i> (2013)
<i>P. megacystidiatus</i>	Yunnan, SW China	Probably a synonym of <i>P. yunnanensis</i>	Ye <i>et al.</i> (2014)
<i>P. microsquamus</i>	Hainan, southern China	Accepted	Wu <i>et al.</i> (2021)
<i>P. nigrisquamus</i>	Yunnan, SW China	Accepted	Wu <i>et al.</i> (2021)
<i>P. nigrobruneus</i>	Yunnan, SW China	Accepted	Wu <i>et al.</i> (2021)
<i>P. orientalis</i>	Malaysia	Confirmed as absent from China	Corner (1970), Zeng <i>et al.</i> (2013)
<i>P. orientalis</i> var. <i>brevisporus</i>	Singapore	Confirmed as absent from China	Corner (1970), Li & Song (2003)
<i>P. pachycystidiatus</i>	Yunnan, SW China	Accepted	Zeng <i>et al.</i> (2013)
<i>P. parvisporus</i>	Singapore	Accepted	Corner (1970), Zeng <i>et al.</i> (2013)
<i>P. pruinatus</i>	Anhui, eastern China	Accepted	Zhao <i>et al.</i> (2018)
<i>P. pusillus</i>	Thailand	Accepted	Chuankid <i>et al.</i> (2019), Wu <i>et al.</i> (2021)
<i>P. rhodoxanthus</i>	North America	Confirmed as absent from China	Schweinitz (1822), Li & Song (2003)
<i>P. rubeolus</i>	Yunnan, SW China	Accepted	Zeng <i>et al.</i> (2013)
<i>P. rubiginosus</i>	Thailand	Accepted	Neves <i>et al.</i> (2012), Wu <i>et al.</i> (2021)
<i>P. rubrosquamosus</i>	Yunnan, SW China	Accepted	Zeng <i>et al.</i> (2013)
<i>P. rufescens</i>	Singapore	Accepted	Corner (1970), Zeng <i>et al.</i> (2013)
<i>P. scabrosus</i>	Yunnan, SW China	A member of <i>Lentinus</i>	Zang & Zeng (1978), Zeng <i>et al.</i> (2011)
<i>P. subbacillisporus</i>	Yunnan, SW China	Accepted	Chuankid <i>et al.</i> (2019)
<i>P. subrubeolus</i>	Thailand	Accepted	Chuankid <i>et al.</i> (2019), Wu <i>et al.</i> (2021)
<i>P. sulphureus</i>	West Bengal, India	Confirmed as absent from China	Berkeley (1851), Li & Song (2003)
<i>P. tenuissimus</i>	Hainan, southern China	Accepted	Wu <i>et al.</i> (2021)
<i>P. yunnanensis</i>	Yunnan, SW China	Accepted	Zeng <i>et al.</i> (2013)
<i>Pulchroboletus erubescens</i>	Hainan, southern China	Accepted	This study

Table 2. (Continued).

Species	Type locality	Treatment	References
<i>Xerocomus albobrunneus</i>	Congo	Confirmed as absent from China	Heinemann (1951), Li & Song (2003)
<i>X. albotomentosus</i>	Hainan, southern China	Accepted	This study
<i>X. anthracinus</i>	Fujian, SE China	Re-evaluated	Zang <i>et al.</i> (1991)
<i>X. astraeicolopsis</i>	Anhui, eastern China	Re-evaluated	Ying & Wang (1981)
<i>X. badius</i>	Former Czechoslovakia	Transferred to <i>Imleria</i>	Fries (1821), Li & Song (2003), Vizzini (2014)
<i>X. bambusicola</i>	Yunnan, SW China	Re-evaluated	Zang <i>et al.</i> (1999)
<i>X. cheoi</i>	Yunnan, SW China	Transferred to <i>Hourangia</i>	Chiu (1948), Zhu <i>et al.</i> (2015)
<i>X. cuneipes</i>	Martinique	Confirmed as absent from China	Pegler (1983), Li & Song (2003)
<i>X. davidlicola</i>	Yunnan, SW China	Re-evaluated	Zang <i>et al.</i> (1999)
<i>X. fraternus</i>	Yunnan, SW China	Accepted	Wu <i>et al.</i> (2016)
<i>X. fulvipes</i>	Yunnan, SW China	Accepted	Wu <i>et al.</i> (2016)
<i>X. fuscatus</i>	Hainan, southern China	Accepted	This study
<i>X. heterocystides</i>	Sichuan, SW China	Re-evaluated	Ying (1986)
<i>X. illudens</i>	America	Confirmed as absent from China	Singer (1945a), Li & Song (2003)
<i>X. impolitus</i>	Europe	Transferred to <i>Hemileccinum</i>	Fries (1838), Li & Song (2003), Šutara (2008)
<i>X. junghuhnii</i>	Indonesia	Confirmed as absent from China	Höhnelt (1914), Li & Song (2003)
<i>X. magniporus</i>	Yunnan, SW China	Re-evaluated	Zang & Petersen (2004)
<i>X. miricystidius</i>	Yunnan, SW China	Re-evaluated	Zang (1996)
<i>X. morrisii</i>	North America	Confirmed as absent from China	Peck (1909), Li & Song (2003)
<i>X. nigropunctatus</i>	Yunnan, SW China	Transferred to <i>Hourangia</i>	Chiu (1948), Zhu <i>et al.</i> (2015)
<i>X. parvulus</i>	Japan	Confirmed as absent from China	Hongo (1963), Li & Song (2003)
<i>X. parvus</i>	Sichuan, SW China	Re-evaluated	Ying (1986)
<i>X. phaeocephalus</i>	Singapore	Confirmed as absent from China	Patouillard & Baker (1918), Li & Song (2003)
<i>X. piceicola</i>	Gansu, NW China	Accepted	Zang & Yuan (1999)
<i>X. porophyllus</i>	Guangdong, southern China	Transferred to <i>Xanthoconium</i>	Yan <i>et al.</i> (2013), Wu <i>et al.</i> (2016)
<i>X. pseudostrobilomyces</i>	Yunnan, SW China	Re-evaluated	Chiu (1948)
<i>X. punctilifer</i>	Yunnan, SW China	A synonym of <i>Hou. cheoi</i>	Chiu (1948)
<i>X. puniceiporus</i>	Guangdong, southern China	Accepted	Zhang <i>et al.</i> (2012)
<i>X. puniceus</i>	Yunnan, SW China	Transferred to <i>Boletellus</i>	Chiu (1948), Wang <i>et al.</i> (2002)
<i>X. rubellus</i>	Europe	Transferred to <i>Hortiboletus</i>	Krombholz (1836), Li & Song (2003), Vizzini (2015)
<i>X. rugosellus</i>	Yunnan, SW China	Accepted	Chiu (1948)
<i>X. satisfactus</i>	Singapore	Confirmed as absent from China	Corner (1972), Phurba <i>et al.</i> (2018)
<i>X. sinensis</i>	Hainan, southern China	Transferred to <i>Neoboletus</i>	Zang <i>et al.</i> (2001), Vizzini (2014)
<i>X. spadiceus</i>	Europe	A synonym of <i>X. ferrugineus</i>	Fries (1838), Li & Song (2003), Kojta <i>et al.</i> (2015)
<i>X. subdaedaleus</i>	Sichuan, SW China	Re-evaluated	Ying (1986), Li & Song (2003)
<i>X. subpaludosus</i>	Yunnan, SW China	Transferred to <i>Hortiboletus</i>	Chiu (1948), Wu <i>et al.</i> (2016)
<i>X. subparvus</i>	Yunnan, SW China	Accepted	Wu <i>et al.</i> (2016)
<i>X. subtomentosus</i>	Europe	Confirmed as absent from China	Linnaeus (1753), Li & Song (2003)
<i>X. sylvestris</i>	Sri Lanka	Confirmed as absent from China	Petch (1922), Li & Song (2003)
<i>X. tengii</i>	Fujian, SE China	Re-evaluated	Zang <i>et al.</i> (2002)
<i>X. velutinus</i>	Yunnan, SW China	Accepted	Wu <i>et al.</i> (2016)
<i>X. versicolor</i>	Europe	A synonym of <i>Hortiboletus rubellus</i>	Rostkovius (1844), Li & Song (2003)
<i>X. yunnanensis</i>	Yunnan, SW China	Accepted	Chiu (1948)

Note: NW = northwestern, SE = southeastern, SW = southwestern.



*X. anthracinus*, *X. astraeicolopsis*, *X. bambusicola*, *X. davidicola*, *X. heterocystides*, *X. magniporus*, *X. miricystidius*, *X. parvus*, *X. piceicola*, *X. pseudostrobilomyces*, *X. subdaedaleus*, and *X. tengii* (Table 2), which have no molecular data from type specimens. In order to re-evaluate these taxa, more collections from a wide area (including the type locality), and more DNA sequence data should be obtained before elucidating their true taxonomic relationships to other *Xerocomus* species.

Biogeographic connections between China and North America/Europe have been discussed in boletes (Mueller *et al.* 2001, Li *et al.* 2009, 2014, Feng *et al.* 2012, Zeng *et al.* 2013, 2016). So far, no disjunct populations of the same putative species of *Xerocomoideae* have been found between China and North America/Europe. The similarities in *Xerocomoideae* species between subtropical-tropical China and Southeast Asia/South Asia suggest a close biogeographic connection between these regions, as they share several common taxa, i.e., *A. longicollis*, *Bol. emodensis*, *H. indecorum*, *P. bellus*, *P. bogoriensis*, *P. castanopsisidis*, *P. parvisporus*, *P. pusillus*, *P. rubiginosus*, *P. rufescens*, and *P. subrubeolus*. Similar affinities have been observed for other fungi as well (Zeng & Jiang 2020). In addition, we also noted that China and Japan share several common species, such as *A. viscidipes*, *Bol. areolatus*, and *Hei. japonicus*.

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## DECLARATION ON CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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**Supplementary Material:** <https://studiesinmycology.org/>

**Table S1.** Taxa, vouchers, locations, and GenBank accession numbers of published/unpublished (except for newly generated) sequences used in this study.